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JESO Editor-in-chief: C. MACQUARRIE
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K.W. Neatby Building, 960 Carling Avenue,
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BURYING BEETLES OF THE GENUS *NICROPHORUS* FABRICIUS (COLEOPTERA: SILPHIDAE) FROM NORTHERN ONTARIO AND AKIMISKI ISLAND, NUNAVUT

J. L. RINGROSE[1], S. V. LANGER[2], K. J. FLEMING[2], T. O. BURT[3], D. R. BOURNE[2], R. BRAND[4], AND D. V. BERESFORD[3,5*]

[1]Regional Operations Division, Ontario Ministry of Natural Resources and Forestry, 479 Government Street, Dryden, Ontario, Canada P8N 3K9

Abstract

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From 2008–2015 we sampled for species of *Nicrophorus* Fabricius from northern Ontario and nearby Akimiski Island, Nunavut, using a variety of methods. We report on new range records, including a known range extension for *Nicrophorus pustulatus* Herschel and *Nicrophorus sayi* Laporte in Ontario, and first territorial records for 3 species in Nunavut: *Nicrophorus hebes* Kirby, *N. investigator* Zetterstedt, and *N. pustulatus*.

Introduction

Burying or sexton beetles of the genus *Nicrophorus* Fabricius (Coleoptera: Silphidae) are large black and red or orange beetles (Fig. 1) known for burying small vertebrate carcasses on which they rear their broods. There are nine species currently known to live in Ontario. One species that was previously found in southern Ontario, *Nicrophorus americanus* Olivier, is now extirpated. It was last recorded in 1972 from the southernmost part of the province near Harrow, Ontario (COSEWIC 2011). A second species, *Nicrophorus hybridus* Hatch and Angell is either rare or extinct in the province (Peck and Miller 1993,

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* Author to whom all correspondence should be addressed.
[2] Environment and Life Sciences Graduate Program, Trent University, 2140 East Bank Drive Peterborough, Ontario, Canada K9J 7B8
[3] Zoologisches Forschungsmuseum Alexander Koenig, Leibniz Institut für Biodiversität der Tiere, Adenauerallee 160, D–53113 Bonn, Germany; University of Bonn (Rheinische Friedrich–Wilhelms–Universität Bonn), Bonn, Germany
[4] Alberta Environment and Parks, 4919 51 Street, Rocky Mountain House, Alberta, Canada T4T 1A9
[5] Trent School of the Environment and Department of Biology, Trent University, 2140 East Bank Drive, Peterborough, Ontario, Canada K9L 1Z8
email, davidberesford@trentu.ca

NHIC 2018), based on specimen records almost a century old. A third species from Ontario, *Nicrophorus pustulatus* Herschel, previously once thought to be rare (Anderson and Peck 1985), is now known to be much more common now that details of its natural history have been documented (LeGros *et al*. 2010; Brown and Beresford 2016; Wettlaufer *et al*. 2018). Unlike other species in this genus, *N. pustulatus* is a parasitoid of snake eggs (Blouin-Demers and Weatherhead 2000; Keller and Heske 2001; Smith *et al.* 2007) and may have conservation relevance for rare or endangered oviparous snake species (LeGros *et al*. 2010; Brown and Beresford 2016).

The distributions of species of *Nicrophorus* across southern Ontario have been documented extensively and are reasonably well known. In contrast, distributions across the more remote parts of northern Ontario are not known at all. In this paper, we summarize the results of several surveys for species of *Nicrophorus* undertaken across the northern part of the province of Ontario, and neighboring Akimiski Island in James Bay, Nunavut. We report a known range extension for *N. pustulatus* in northern Ontario, and the first territorial records of three species in Nunavut.

FIGURE 1. Two species of burying beetles, *N. investigator* (left) and *N. pustulatus* (right), showing typical elytral color patterning. Drawings by Trevor Burt.

Materials and Methods

We collected in northern Ontario from 2009–2015 and on Akimiski Island, Nunavut from 2008–2014. The northern Ontario samples were collected as part of a large–scale biological survey of animal and plant taxa undertaken by the Ontario Ministry of Natural Resources and Forestry (MNRF) Far North Survey (FNSAP 2010 described in Ringrose *et al*. 2013), between 2009 and 2014. Sampling was also conducted in Moosonee Ontario in 2010 and 2015.

On Akimiski Island, Nunavut, sampling took place at the Ontario Ministry of Natural Resources and Forestry (MNRF) biological research station (N 53°6'18", W 80°57'25"), as part of a larger ongoing biodiversity survey, in August 2008 and the last two weeks of July from 2009–2014. All specimens were hand-collected from dead adult or immature geese that had been found along the coast of James Bay. Whenever these were available, carcasses were wired to the trunks of willow shrubs to prevent them from being removed by polar bears or foxes, and inspected each day for beetles (Fig. 2).

Collecting methods

Bottle traps (LeGros traps) (LeGros and Beresford 2010, Langer *et al*. 2016), were constructed from 2 L pop or soda bottles and baited with rotting beef liver, chicken hearts, or chicken drumsticks. Beetles attracted to the bait fell into a collecting bottle filled

FIGURE 2. Typical landscape of Akimiski Island, and a dead goose wired to an adjacent shrub to prevent it being removed by scavengers (inset). Burying beetles were captured by hand each day at the dead goose. The net and collecting bottle suspended above the goose was used to catch blow flies.

with propylene glycol purchased locally as non-toxic RV antifreeze. Traps were hung from overhanging tree branches approximately two meters above the ground. These traps were often damaged by wildlife.

Specimen preparation and analysis

All samples were stored in 80% denatured ethanol and later pinned. Specimens were identified using Anderson and Peck (1985). Taxon concepts follow Anderson and Peck (1985) with the exception of *Nicrophorus vespilloides* Herbst. Recent work (Sikes *et al.* 2016) has shown that what was considered *N. vespilloides* across Canada is likely two species, *Nicrophorus hebes* Kirby in the far northwest and *N. vespilloides* further east. Thus, any of what was called *N. vespilloides* in Ontario are now *N. hebes* (Fig. 6 in Sikes *et al.* 2016).

Current or known ranges were based on the maps presented in Anderson and Peck (1985). These ranges, as well as our own new records, were used to construct distributional maps for species of *Nicrophorus* for Ontario. We traced a polygon by joining the dots from west to east using individual species maps of Anderson and Peck (1985) to describe the known general distribution of each species within Ontario (the shaded regions in Fig. 3).

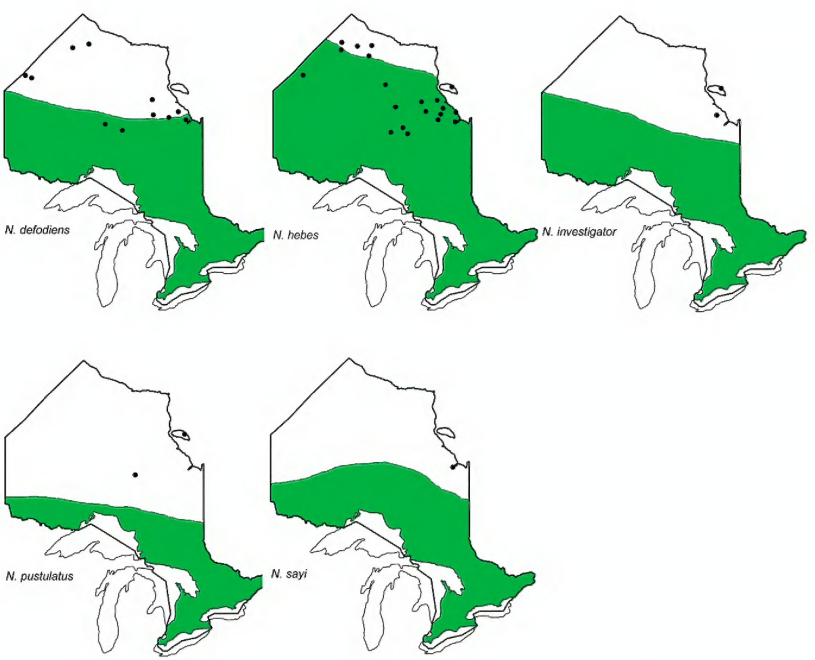

FIGURE 3. Five distribution maps (one for each species), arranged by species name left to right in alphabetical order. The known range for each (green shaded area) was based on the range maps found in Anderson and Peck (1985); our records are the black spots.

Pinned specimens are housed at Trent University in the Entomology Lab, Peterborough, Ontario. A reference collection of voucher specimens has been sent to the Canadian National Collection of Insects, Ottawa, Ontario.

Results

In total, we collected 396 burying beetles, from 5 species: 369 specimens from northern Ontario, and 27 from Akimiski Island, Nunavut (Table 1, Appendix). Four species were caught outside of their known ranges (Fig. 3): *Nicrophorus defodiens* Mannerheim in Ontario, *Nicrophorus investigator* Zetterstedt on Akimiski Island and Ontario (51° 40' N, 81° 18' W), *N. pustulatus* on Akimiski Island and Ontario (50° 56' 46" N, 84° 51' 5" W), and *Nicrophorus sayi* Laporte in Ontario (51° 14' 14" N, 80° 41' 24" W) (Fig. 3).

Discussion

Three of the species we found are first records of occurrence for the territory of Nunavut: *N, hebes*, *N. investigator,* and *N. pustulatus*. In Ontario, our collections of *N. defodiens* extends the known range northward to the northern James Bay coast. All 5 species were collected in regions of discontinuous permafrost (Crins *et al*. 2009). Along Ontario's northern coast where there is permanent permafrost (Crins *et al*. 2009), the upper 1 to 2 m of soil thaws out each summer (Tam 2009), which would not hinder burying by *Nicrophorus* beetles, making it likely that both *N. defodiens* and *N. hebes* occur along the northern coast, although Peck (1986) has shown that carcass burial is not always necessary for reproduction.

Nicrophorus defodiens has been collected throughout Canada except in Nunavut (Anderson and Peck 1985; Majka 2011). Our collections fill in distribution gaps in northern Ontario and our collection of an individual approximately 90 km south of Fort Severn,

TABLE 1: Burying beetle (Coleoptera: Silphidae) number collected and species composition by sampling location, from 2008– 2015 throughout Ontario and Akimiski Island, Nunavut.

	N. defodiens	*N. hebes*	*N. investigator*	*N. pustulatus*	*N. sayi*
Northern Ontario					
Bottle trap	145	212	1	0	1
Hand caught	7	2	0	1	0
Akimiski Island, Nunavut					
Hand caught at bait	0	1	25	1	0

Ontario extends the range in Ontario northward some 500 km from the previous record at Moosonee (Fig. 3). This is a common species, largely restricted to dry, upland, and boreal forests (Anderson 1982; Beninger and Peck 1992).

Nicrophorus hebes is a widely distributed species found throughout Canada. Previously identified as *N. vespilloides* (Sikes *et al.* 2016), it has been documented in all provinces and all territories except Nunavut (Anderson and Peck 1985; Majka 2011; Sikes *et al.* 2016). Our collection of one specimen on Akimiski Island is the first record of this species in Nunavut. Our records from Ontario are consistent with the current range of this species, albeit extending the known range northward.

Nicrophorus hebes is a wetland specialist largely confined to marsh areas, bogs, and fens (Anderson 1982; Beninger and Peck 1992), which may explain why we caught so many of them; much of our work took place in saturated peatlands in the Hudson Bay Lowlands (Crins 2009).

There is compelling evidence that, unlike the rest of Canada, specimens in Alaska and the northwestern region of Canada are not *N. hebes* but are in fact true *N. vespilloides* (Sikes *et al.* 2016), a widespread Eurasian species. Whether the distributions of these two species overlap needs to be more fully studied.

Nicrophorus investigator has been found in all regions of Canada except Nunavut (Anderson and Peck 1985; Majka 2011). Our collection of this species on Akimiski Island is the first record of the species in the territory, and our Ontario records fill in a distributional gap in the province. A record from this region was to be expected. There are records from Labrador and Quebec's west coast of Hudson Bay to the east, the Yukon and Northwest Territories, and Alaska in the west (Anderson and Peck 1985). Unlike the other species we caught, this species is known to breed on larger carcasses such as those of rabbits (Peck 1986), and our finding *N. investigator* on dead geese (Fig. 2) is consistent with this pattern.

Nicrophorus pustulatus is not known from two Canadian provinces: British Columbia, and Newfoundland and Labrador, nor has it been reported in any of the Canadian territories (Anderson and Peck 1985; Majka 2011). *Nicrophorus pustulatus* is generally found throughout the southern part of Ontario, with records from as far north as the region east of Lake Nipigon. We caught two individuals further north, one southeast of Marten Falls which extends the known range in Ontario northward by approximately 130 km (Fig. 3), and one from Akimiski Island, Nunavut, making it the first record of this species in this territory. Based on low numbers in general surveys, it is widely reported to be uncommon or rare (Trumbo and Thomas 1998; Katovich *et al.* 2005) and not often captured using traps baited with carrion (Anderson and Peck 1985; Keller and Heske 2001; Owings and Picard 2015). Specimens are more commonly captured during the night at lights (Anderson and Peck 1985; Robertson 1992), although this species has been collected from raccoon carcasses (Katovich *et al.* 2005) and rat-baited pitfall traps (Trumbo and Thomas 1998). It is reported to be rare and seldom collected in baited traps (Anderson and Peck 1985; Owings and Picard 2015); most commonly it is captured at night near light sources (Anderson and Peck 1985). This apparent rarity is likely an artifact of the sampling method employed. Recent work has shown the species to be more common than previously thought in some areas. For example, *N. pustulatus* is often collected when baited traps are placed 6 m high in tree canopies (LeGros and Beresford 2010; Brown and Beresford 2016; Wettlaufer *et al.*

2018) in areas where they are otherwise not captured in lower traps (LeGros and Beresford 2010). In this paper, none of our sampling methods included the use of high traps; both of our specimens were collected by hand at ground level.

Many aspects of the life history of *N. pustulatus* in the wild still need to be determined. Captive mated pairs of this species can rear broods successfully on small rodents (Rauter and Rust 2012), larger carcasses (Trumbo 1992; Robertson 1992), turtle eggs, and snake eggs (Trumbo 2006; Smith *et al*. 2007). However in the wild, immature *N. pustulatus* have only been documented as snake egg parasitoids of three species: grey rat snakes *Pantherophis spiloides* (A. M. C. Duméril, Bibron and A. H. A. Duméril) (Blouin-Demers and Weatherhead 2000; Keller and Heske 2001, as *Elaphe obsoleta*), fox snakes (*Pantherophis vulpinus* (Baird & Girard)) (Blouin-Demers and Weatherhead 2000, as *Elaphe vulpine*), and ring-neck snakes (*Diadophis punctatus* L.) (LeGros *et al*. 2010), and is likely able to use eggs from any snake species (Smith *et al*. 2007). The northernmost records of any oviparous snake in Ontario are ring-necked snakes, from in the region just north of Lake Superior (Cook 1984). There are no oviparous snakes known to be found as far north as either of our two records from Akimiski Island or Martin Falls, evidence that *N. pustulatus* must also reproduce successfully in the wild on either other eggs or animal carcasses. We still do not know what *N. pustulatus* breeds on in these northern populations, to what extent it uses snake eggs when suitable snake species are present, how common *N. pustulatus* is across its range, and to what extent its apparent scarcity in general surveys is an artifact of sampling method.

Finding *Nicrophorus sayi* is consistent with its known preference for dry forested areas (Anderson and Peck 1985). Known to be an early season species (Anderson and Peck 1985), our single specimen record of *N. sayi* is likely due to our sampling in mid-summer, and catching it near Moosonee was not unexpected (Fig. 3).

Although species of *Nicrophorus* have been widely studied in the past, there is still much to learn from publishing up-to-date records of even such large and colorful insects as burying beetles (Majka and Sikes 2009). Knowing the natural history and habitat preferences of these species, and species in general, enables us to predict the geographic extent of these species, where to look for them, and how to sample them, necessary information for assessing the at-risk status of species.

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APPENDIX 1. Catch data for *Nicrophorus* species listed as *species* year: day month Lat. Long. (catch). The Akimiski Island samples were all collected at the same site.

Akimiski Island, Nunavut, N53°6'18" W80°57'25"
Nicrophorus hebes 2011: 25 July (1). *Nicrophorus investigator* 2008: 7 Aug (7), 10 Aug (2); 2009: 22 July (1), 23July (1), 28 July (4); 2010: 12 Aug (5); 2011: 20 July (1); 2013: 28 July (3); 2014: 30 July (1). *Nicrophorus pustulatus* 2011: 28 July (1).

Moosonee, Ontario
Nicrophorus defodiens 2012: 13 July N51°14'14" W80°41'24" (112); 2015: 30July N51°39'60" W81°17'60" (24). *Nicrophorus hebes* 2012: 12 July N51°14'14" W80°41'24" (28), 13 July N51°14'14" W80°41'24" (19). *Nicrophorus investigator* 2015: 30 July N51°39'60" W81°17'60" (1). *Nicrophorus sayi* 2012: 13 July N51°14'14" W80°41'24" (1).

Northern Ontario
Nicrophorus defodiens 2011: 1 July N53°28'6" W93°2'6" (1), 10 July N53°36'8" W93°32'13" (1), 10 July N53°36'8" W93°32'13" (1), 29 June N53°28'6" W93°2'6" (1); 2012: 1 July N51°29'45" W83°17'46" (1), 14 July N51°21'26" W82°3'15" (2), 15 July N52°18'40" W83°22'42" (2); 2013: 2 July N51°0'40" W87°8'54" (1), 7 July N50°41'4" W85°47'22" (1), 7 July N50°40'46" W85°46'57" (3); 2014: 8 Aug N55°16'31" W88°27'16" (1), 9 Aug N55°4'41" W89°45'6" (1). *Nicrophorus hebes* 2009: 31 July N50°36'48" W84°28'36" (1); 2010: 17 July N53°13'35" W86°14'5" (1); 2011: 17 July N53°43'57" W92°46'3" (2); 2012: 8 July N51°47'43" W83°1'57" (2), 8 July N51°47'30" W83°2'16" (9), 8 July N52°23'36" W82°8'2" (3), 15 July N51°21'7" W82°3'23" (3), 15 July N51°21'22" W82°3'50" (13), 15 July N52°18'40" W83°22'42" (11), 17 June N51°39'25" W81°50'59" (2), 17 June N51°44'32" W80°39'6" (14), 24 June N51°57'58" W81°39'38" (1), 24 June N51°58'25" W81°39'23" (2); 2013: 6 July N50°41'4" W85°47'22" (1), 7 July N50°41'4" W85°47'22" (5), 7 July N50°40'46" W85°46'57" (19), 13 July N50°56'13" W84°51'6" (1), 15 July N50°56'30" W84°51'37" (24), 23 July N52°2'11" W85°25'56" (2); 2014: 7 Aug N54°45'18" W87°32'29" (1), 8 Aug N55°16'31" W88°27'16" (5), 8 Aug N55°18'34" W87°19'8" (1), 8 Aug N54°45'18" W87°32'29" (15), 9 Aug N55°4'41" W89°45'6" (25), 9 Aug N55°28'36" W89°42'5" (4). *Nicrophorus pustulatus* 2013: 15 July N50°56'5" W84°51'52" (1).

SAMPLING SYRPHIDAE USING MALAISE AND NZI TRAPS ON AKIMISKI ISLAND, NUNAVUT

K. A. VEZSENYI[1*], J. H. SKEVINGTON[2,3], K. MORAN[2,3], A. D. YOUNG[2,3], M. M. LOCKE[2], J. A. SCHAEFER[4], AND D. V. BERESFORD[4]

[1]Trent University, ENLS graduate program, 1600 West Bank Drive, Peterborough, Ontario, Canada, K9L 0G2
email, kathrynvezsenyi@trentu.ca

Abstract *J. ent. Soc. Ont.* 150: 11–26

Flower flies (Diptera: Syrphidae) are a diverse group of pollinators found almost worldwide. Species surveys of these flies provide unique challenges as they can be difficult to collect due to different trapping biases. Here, we test the efficacy of the Nzi trap for use in the collection of syrphids by comparing the richness and abundance of syrphids caught in a Malaise trap and Nzi trap, July, 2012-2017 on Akimiski Island, Nunavut. We found that the Nzi trap caught many of the same species and in similar abundances as the Malaise trap, except for *Platycheirus kelloggi* (Snow), of which more were caught in the Nzi than the Malaise. The high capture rate of *P. kelloggi* using Nzi traps could be due to the flies' unique shelter- or mate-seeking behaviours related to structure or colour. Using collections from 2008-2017, we also provide new territory records for 55 species and range extensions for 19 species. Two of these, *Platycheirus kelloggi* and *Platycheirus latitarsis* Vockeroth, had previously been reported only west of the Rocky Mountains.

Introduction

Flower flies (Diptera: Syrphidae), also known as hover flies or syrphids, are a common and diverse family of pollinators (Miranda *et al*. 2013). To elucidate the impact of

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* Author to whom all correspondence should be addressed.
[2] Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, K.W. Neatby Building, 960 Carling Avenue, Ottawa, ON, Canada, K1A 0C6
[3] Carleton University, Department of Biology, 209 Nesbitt Building, 1125 Colonel By Drive, Ottawa, ON, Canada, K1S 5B6
[4] Trent Department of Biology, Trent University,
2140 East Bank Drive, Peterborough, Ontario, Canada K9L 1Z8

individual flower fly species on wild pollination, we first need to understand those species' geographic distributions. Unfortunately, our knowledge of species ranges is often hampered by a lack of species surveys in remote locations. In this paper, we report on the syrphid species caught on Akimiski Island, Nunavut, a northern island in James Bay, Canada. Few studies of insect diversity have been conducted on Akimiski Island, with previous studies focusing on biting flies (Beresford *et al.* 2010) and beetles (Fleming and Beresford 2016; DeGasparro *et al.* 2018).

Species surveys of syrphids are often challenging due to the specialized niches that many species inhabit. Hand netting is the most common sampling method, although results may be influenced by time of day, season, habitat, and collector expertise (D'Amen *et al.* 2008; Gill and O'Neal 2015). The use of passive intercept traps to capture flying adults, such as Malaise traps, removes many of these problems as they can be placed for longer periods of time. While Malaise traps capture a wide variety of insect species with little effort (Brown 2005), they may miss species that are trap-shy or occur only in specialized niches. Traps that target pollinators, such as pan traps, have produced mixed results for sampling syrphids (Campbell and Hanula 2007; Namaghi and Husseini 2009; Proctor *et al.* 2012).

Here, we report on syrphid species collected using five different methods, along with range extensions and new species records for Nunavut. Some syrphid species are attracted to blue (Chen *et al.* 2004; Campbell and Hanula 2007), so it is likely that blue and black cloth traps, or Nzi traps (Mihok 2002), may provide an additional tool for sampling previously under-collected species. To test this hypothesis, we compared the Nzi trap catches to Malaise trap catches deployed at the same time and location. Malaise traps are similar to mist nets, intercepting flying insects, and are non-attracting (more or less). As a starting point, we surmised that the effectiveness of an intercept trap might be based on its interception surface area. Our null hypothesis was that the Nzi trap works as a smaller non-attracting intercept trap along the lines of the Malaise trap, its effectiveness based on interception surface area. Other trapping methods were not included in this analysis as they were not standardized over time, and were used on an *ad hoc* basis.

Materials and Methods

Study site

All collecting took place on Akimiski Island, Nunavut, Canada, at the biological research station (53°6'18"N, 80°57'25"W) operated by the Ontario Ministry of Natural Resources and Forestry. This large island (3,800 km^2) is located in James Bay, near the coast of northern Ontario (Fig. 1). It is part of the Hudson Plains ecozone, with an extensive sand and gravel shoreline, and many bogs, fens, and spruce stands in the interior (Martini and Glooschenko 1984). The mean annual temperature is -3.5ºC, and mean annual precipitation is around 700 mm (Ecological Stratification Working Group 1995). Uninhabited by humans, two thirds of the island is a migratory bird sanctuary, serving as an important stopover site for many migrating shorebirds and geese (Abraham *et al.* 1999; Jefferies *et al.* 2006; Pollock *et al.* 2012).

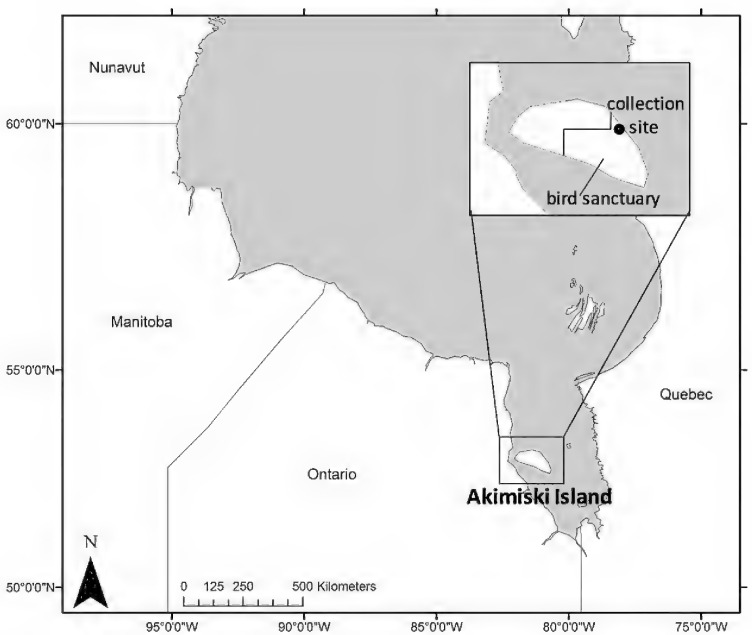

FIGURE 1. Map of the study site on Akimiski Island, Nunavut.

Collection methods

Collecting occurred in the last two weeks of July, 2009–2017, and in June and August, 2008. Trapping methods included Malaise, Nzi, sticky traps, hand netting, and IPY (International Polar Year) traps (McKinnon *et al.* 2008).

We used a single Malaise trap (Fig. 2) (Lightweight Malaise Trap, Townes Style, 176 cm high, 165 cm long, model no. 2868, BioQuip Products, Rancho Dominguez, CA) from 2012 to 2017. This was placed within the research station fenced-in area to prevent polar bears from damaging the trap, 10 m from the Nzi trap.

Nzi traps (Fig. 2) are blue and black cloth traps designed for biting flies (Mihok *et al.* 2006). A single cloth Nzi trap was deployed each year, 2008–2017 (Fig. 2); in 2010 and 2011 a second Nzi trap made from Coroplast® (Coroplast, a division of Great Pacific Enterprises Inc., Granby, QC, and Dallas, TX) plastic panels was also used in addition to the cloth Nzi trap. Nzi and Malaise collecting heads were charged with propylene glycol (non-toxic RV antifreeze) as a drowning agent and preservative; these were emptied every 12 hours (at dawn and dusk), and specimens were stored in 80% ethanol for preparation later.

Different coloured sticky card traps (Beresford and Sutcliffe 2006) were set in August 2008. Coloured Coroplast (black, white, yellow, blue, red) cards, 20 cm x 30 cm, were coated with Tangle Trap® (Tangle Foot Co., Chicago, IL) and screwed to a wooden stake. The stakes were spaced 1 m apart. Acetone was applied to the cards with a dropper

FIGURE 2. Malaise trap (left) and cloth Nzi trap (right) deployed on Akimiski Island, Nunavut, 2017.

so we could remove the specimens. Flies were then removed and pinned, and subsequently soaked in acetone to completely remove the Tangle Trap.

Hand netting took place on an *ad hoc* basis during the day, throughout the sampling period, sweeping over blossoms. Specimens were then pinned.

IPY traps (Gan *et al.* 2009) consisted of a 40 cm wide black screen stretched between two 50 cm tall wooden stakes, with the screen overtop a plastic tray, and the entire structure surmounted by a white plastic funnel leading upward to a collecting bottle. This trap intercepted low flying insects, capturing those that either crawled up or down to escape as well as insects that crawled into the bottom tray (Gan *et al.* 2009). The bottom tray and the upper bottle were charged with soapy water. They were only placed during the sampling period from 2008 to 2009. Fifteen IPY traps were placed near the shoreline between the high tide mark and the beach area along the coast and set about 50 m apart (Gan *et al.* 2009; Beresford *et al.* 2010).

Specimen Preparation

All specimens were pinned; most were first preserved by critical point drying using a Leica critical point dryer (Leica EM CPD300, Leica Microsystems Inc., Concord, ON), then pointed. Identifications were performed using Skevington *et al.* (in press), supplemented by keys from Vockeroth (1992), Miranda *et al.* (2013), and Young *et al.* (2016). The collection is currently housed in the Trent University Entomology lab and will be deposited in the Canadian National Collection of Insects, Arachnids and Nematodes (Ottawa, ON).

Analyses: Nzi and Malaise comparison

We compared the proportion of singleton species, and the number of unique species, caught by Malaise and cloth Nzi traps for the years 2012–2017 with 2×2 contingency table tests for independence (chi square test, $d.f. = 1$).

We also compared the abundance of each species caught by Malaise and cloth Nzi traps for the years 2012–2017. Because the Malaise trap is larger than the Nzi trap, and if Nzi traps do not attract but only intercept, we expected to catch fewer individuals

in the Nzi trap, without making any assumption of how the effective surface area of each trap might change with trap height, direction or placement. The Malaise trap had a surface area of 2.9 m^2 and the Nzi trap had an effective surface area of 1.6 m^2. Based on the simple premise that interception area governs trap rate, our null hypothesis was that trap catches were independent of trap type. We tested this for species with total catches of ten or more individuals using a Fisher's exact test of independence, set up as the total number of a species in each trap type versus the combined number of all other species in each trap type (all years combined). We then used a sequential Bonferroni correction (Sokal and Rohlf 1997) for these tests. These tests were performed using STATISTICA 7 (StatSoft Inc. Tulsa, OK).

We fitted the abundance data, using the total combined Nzi and Malaise catches from 2012–2017, to a log normal distribution following the method used by Preston (Preston 1948; Ludwig and Reynolds 1988). This enabled us to estimate how many species there are in a community, and compare this estimate to how many were caught, providing an estimate of how many additional syrphid species are expected to occur from the study area. In addition, we estimated species richness using several other methods: Chao 1, Chao 2, Jackknife 1, Jackknife 2, and the bootstrap method (Gotelli and Colwell 2011). These were performed using PAST 3.20 (Hammer *et al.* 2001).

Range Extensions

The known ranges were determined for each species caught using the Field Guide to the Flower Flies (Hover Flies) of Northeastern North America (Skevington *et al.* in press). We defined a range extension as a new record for a species more than 400 km away from the nearest previous record or from a line between two previous records that extended the known range in any direction. We defined a gap infill as a new record in an area between previous records that were at least 400 km away, but did not extend the known range in any one direction. This range extension distance was chosen arbitrarily; however, a distance of 400 km crosses a number of plant hardiness zones from north to south, changing plant communities. A distance of 800 km almost always crosses into a different ecozone outside of the Hudson Plains, meaning these records are coming from fundamentally different habitats.

Results

We caught 598 individual syrphids, and were able to identify 553 specimens to 73 species; the remaining 45 individuals could be identified only to genus. These unknowns were either damaged (two specimens) or were females (41 specimens) from genera in which males are required for identification. Although we could not identify these directly to species, we know that at least two of these are additional species as we had no other individuals from these particular groups: *Eupeodes americanus* (Wiedemann)*/pomus* (Curran) (4 individuals), and *Paragus* (*Paragus*) sp. (3 individuals). Of the 73 species collected, 55 were new species records for Nunavut (Table 1A–C). The most abundant species were *Cheilosia latrans* (Walker), making up 20% (n = 103) of all syrphid catches, followed by *Melanostoma mellinum* (Linnaeus) at 12% (n = 36). There were 29 singleton

TABLE 1. All syrphid species records of males (M) and females (F) for Akimiski Island, Nunavut, Canada. A. species found <400 km away from nearest record; B. species found 400–800 km away from nearest record; C. species found >800 km away from nearest record. Sex, counts, trap type, and years caught are included. *= New species record for Nunavut

	Species	Count		Collection method	Years
		M	F		
A: <400 km	**Anasimyia anausis* (Walker)	3		Malaise	2014, 2017
	Chalcosyrphus vecors (Osten Sacken)		1	sticky trap	2008
	Cheilosia latrans (Walker)	64	39	Malaise, Nzi, net	2010, 2012–2017
	**Cheilosia orilliaensis* (Curran)		3	Nzi, net	2010, 2016
	**Cheilosia rita* (Curran)		1	Nzi	2016
	**Cheilosia shannoni* (Curran)	1		Malaise	2016
	**Chrysotoxum derivatum* Walker	6	1	Malaise, Nzi	20012, 2014, 2016–2017
	**Chrysotoxum flavifrons* Macquart		2	Malaise	2017
	**Chrysotoxum plumeum* Johnson	7	13	Malaise, Nzi	20012, 2016–2017
	**Dasysyrphus amalopis* (Osten Sacken)		1	Malaise	2012
	**Dasysyrphus limatus* (Hine)	1		Nzi	2016
	Dasysyrphus venustus (Meigen)		1	Nzi	2016
	**Doros aequalis* Loew		1	Malaise	2014
	**Epistrophe grossularie* (Meigen)	1		sticky trap	2008
	**Epistrophe nitidicollis* (Meigen)		1	Malaise	2013
	**Epistrophella emarginata* (Say)		1	Malaise	2009
	Eristalis brousii Williston	18	18	IPY, net	2008–2010, 2013
	**Eristalis dimidiata* Wiedemann	10	14	IPY, Nzi, sticky trap, net	2008–2011
	**Eristalis flavipes* Walker		2	Malaise, Nzi	2011, 2014
	Eupeodes curtus (Hine)		1	Malaise	2016
	**Eupeodes flukei* (Jones)	1	5	Malaise, Nzi	2015, 2016–2017
	Eupeodes luniger (Meigen)	1		Malaise	2017
	**Eupeodes perplexus* (Osburn)		1	Nzi	2015
	**Ferdinandea buccata* (Loew)		3	Malaise	2017
	Helophilus groenlandicus (Fabricius)		7	IPY	2008
	**Helophilus hybridus* Loew		2	Malaise, Nzi	2015–2016
	Helophilus lapponicus Wahlberg	2		Malaise	2014, 2017
	**Helophilus obscurus* Loew	3	7	Malaise, net	2008, 2013–2016
	**Lapposyrphus lapponicus* (Zetterstedt)	28	25	IPY, Malaise, Nzi, sticky trap, net	2008, 2010, 2012–2017
	Melanostoma mellinum (Linnaeus)	32	40	Malaise, Nzi, net	2012–2017
	**Meligramma guttata* (Fallén)		1	Malaise	2017
	**Meliscaeva cinctella* (Zetterstedt)	4	11	Malaise, Nzi	2013–2017
	**Parasyrphus genualis* (Williston)		1	Malaise	2012
	**Parhelophilus porcus* (Walker)	1	1	Malaise, Nzi	2013, 2015
	**Platycheirus albimanus* (Fabricius)		7	Malaise, Nzi	2010–2012, 2016–2017
	**Platycheirus amplus* (Curran)	2	1	Malaise, Nzi	2015–2016
	Platycheirus clypeatus (Meigen)		1	Nzi	2016
	**Platycheirus granditarsis* (Forster)	1	5	Malaise, Nzi, pitfall, net	2010–2012, 2015–2016
	**Platycheirus hyperboreus* (Staeger)	1		Malaise	2014

TABLE 1 continued...

	Species	Count		Collection method	Years
		M	F		
A: <400 km	**Platycheirus inversus* Ide	1	1	Malaise	2014–2015
	**Platycheirus naso* (Walker)		3	Malaise, Nzi	2012, 2015–2016
	Platycheirus obscurus (Say)		2	Malaise	2013, 2015
	**Platycheirus pictipes* (Bigot)	2	15	Malaise, Nzi	2012, 2015-–2017
	**Platycheirus podagratus* (Zetterstedt)		2	Malaise	2014, 2016
	**Platycheirus varipes* Curran		4	Malaise, Nzi	2012, 2014, 2016–2017
	**Polydontomyia curvipes* (Wiedemann)		1	Malaise	2013
	**Scaeva affinis* Say		1	Malaise+D175	2016
	**Sphaerophoria abbreviata* Zetterstedt	2		Nzi, net	2010, 2015
	Sphaerophoria philanthus (Meigen)	15		Malaise, Nzi, net	2008, 2010, 2012, 2014–2017
	**Syrphus attenuatus* Hine	1		Malaise	2014
	Syrphus ribesii (Linnaeus)		11	Malaise, Nzi	2010, 2012–2016
	Syrphus vitripennis Meigen	1	1	Malaise	2015
	**Toxomerus marginatus* (Say)		1	IPY	2008
	**Volucella facialis* Williston		1	Nzi	2017
B: 400-800 km	**Cheilosia lasiophthalmus* Williston		1	IPY	2009
	**Eupeodes confertus* (Fluke)	1	2	Malaise, Nzi	2013, 2016–2017
	**Megasyrphus laxus* (Osten Sacken)		1	Nzi	2010
	**Meligramma triangulifera* (Zetterstedt)	1		Malaise	2016
	**Orthonevra robusta* (Shannon)	17	24	IPY, Malaise	2008–2009, 2016–2017
	**Paragus haemorrhous* Meigen		1	Malaise	2015
	**Pipiza quadrimaculata* (Panzer)		1	Malaise	2014
	**Platycheirus luteipennis* (Curran)		2	Nzi	2017
	**Syrphus sexmaculatus* (Zetterstedt)		2	Malaise	2014, 2016
C: > 800 km	*Cheilosia laevis* (Bigot)	1		Malaise	2016
	Eristalis hirta Loew		4	net	2010, 2013
	**Eumerus strigatus* (Fallén)	1		net	2009
	**Neocnemodon elongata* (Curran)	1		Malaise	2016
	**Pipiza atrata* Curran		1	Malaise	2017
	**Platycheirus jaerensis* (Nielsen)	1		IPY	2009
	**Platycheirus kelloggi* (Snow)		16	Malaise, Nzi	2009–2010, 2012, 2016–2017
	**Platycheirus latitarsis* Vockeroth	1		Nzi	2016
	**Platycheirus neoperpallidus* (Young)	3		Nzi	2017
	Platycheirus nielseni Vockeroth	1		Malaise	2017

species, representing 39.7% of all species identified but only 4.8% of the total catch (29/598 specimens).

The catches by trap type are summarized in Table 2. Most specimens were obtained using the Malaise traps and the Nzi traps (by species Table 1, summary Table 2).

Estimates of species richness were (in descending order): Jackknife 2 = 131.76, Chao 2 = 123.14 (SD = 21.79), Chao 1 = 116.2 (range 79.92 to 118.1), Jackknife 1 = 109 (SD = 10.39), Bootstrap = 88.5, Preston's log-normal = 76.1.

TABLE 2: Syrphid individuals collected by each trap type for each year of sampling on Akimiski Island, Nunavut, Canada. Blanks indicate the years when traps were not deployed.

Year	Malaise trap	NZI	Sticky trap	Netted	IPY trap
2008		1	12	9	77
2009		1		1	8
2010		23		17	
2011		3		2	
2012	22	13		0	
2013	24	2		7	
2014	70	11		0	
2015	29	15		0	
2016	38	55		10	
2017	109	39		0	
Total	292	163	12	46	85

Range Extensions

We found 54 species that were expected in this area, as they were found less than 400 km away from the nearest record (Table 1A). There were nine species found 400–800 km away from the nearest record (Table 1B), and 10 species records that were more than 800 km away from the nearest collection record (Table 1C). Of the species from Table 1C, three of these (*Cheilosia laevis* (Bigot), *Eristalis hirta* Loew, and *Platycheirus neoperpallidus* (Young)) represent large gap infills, with the others representing large range extensions.

Trap Analysis

Overall, we caught 51 species (271 individuals) in the Malaise traps and 29 species (122 individuals) in the Nzi traps, 2012–2017. Of these, Malaise and Nzi traps had more-or-less the same proportion of singletons (21 and 8 singleton species respectively; 2×2 contingency test: $\chi^2 = 0.71$, $P = 0.40$). For 2012–2017, Malaise and Nzi traps each caught 33 and 11 unique species respectively, which was not significantly different (2×2 contingency test: $\chi^2 = 1.64$, $P = 0.20$).

When we compared catches by species, three species appeared to have higher Nzi trap numbers than expected if the Nzi trap was simply acting as a flight intercept trap: *Lapposyrphus lapponicus* (Zetterstedt) (Malaise: Nzi, 17:17), *Platycheirus pictipes* (Bigot) (7:10), and *Platycheirus kelloggi* (Snow) (3:10). After we applied the sequential Bonferroni correction, only *P. kelloggi* showed a significant trap bias (Fisher exact test, $P = 0.0011$, sequential Bonferroni corrected $\alpha = 0.05/8 = 0.00625$), with substantially higher numbers in the Nzi trap. From this, we tested whether these traps differed in how many *Platycheirus* spp. (excluding *P. kelloggi*) were caught, and found significantly more *Platycheirus* spp. caught by the Nzi trap (26) than by the Malaise trap (24) ($\chi^2 = 11.99$, $P = 0.0005$).

The rarefaction of the Malaise and Nzi trap catches (Fig. 3) shows that, when corrected for sample size, the number of species caught in each trap was more or less the same, although the curve for the Nzi trap was somewhat lower.

Discussion

Our Nzi and Malaise comparison shows that, aside from *Platycheirus kelloggi,* the Nzi trap likely functions as a flight intercept trap for syrphids. Although the Nzi traps collected a number of species that the Malaise did not, most were composed of single individuals, and from our analysis, these individuals were most likely a random occurrence in one of the two traps.

Like many syrphids, *Platycheirus* Lepeletier & Serville often congregate around specific landscape features in order to find mates (Barkalov and Nielsen 2007). However, unlike most syrphids, *Platycheirus* are often active on overcast or light rain days, and in cool, shaded areas (Barkalov and Nielsen 2007; Skevington *et al*. in press). All individuals of *P. kelloggi* collected in Nzi traps were female, which indicates that this species likely seeks out a different microhabitat when looking for mates. It is possible that *P. kelloggi* and other *Platycheirus* were collected more frequently in the Nzi traps because other syrphids avoid the dark colours and shaded areas created by the trap. Conversely, it is possible that female *P. kelloggi* were specifically attracted to the Nzi trap due to the colour, mistaking it

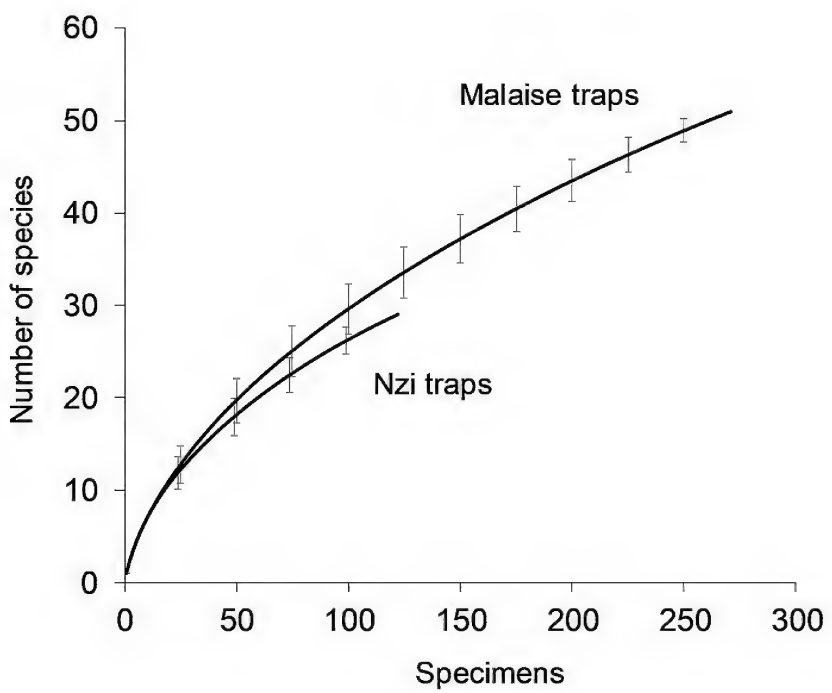

FIGURE 3. Rarefaction curve of Malaise and Nzi syrphid sampling data from 2012–2017 on Akimiski Island, Nunavut. The error bars represent standard deviation.

either for an oviposition site or for a male conspecific. The latter scenario could be taking place because male *P. kelloggi*, unlike most *Platycheirus* species, have an overall blue colouration. This could explain why only *P. kelloggi* was significantly associated with the traps, as opposed to other shade-loving species of *Platycheirus*.

Studies with blue traps from warmer regions have reported catches of different species in high abundance: *Allograpta obliqua* (Say) (Chen *et al*. 2004) and *Melangyna viridiceps* (Macquart) (Broughton and Harrison 2012), so it is likely that using an Nzi trap south of our study area would yield different proportions of species. The total number of individuals caught by the Nzi trap is still more than expected given the smaller trap surface. Even so, for those interested in general syrphid surveys, the Malaise remains the better choice, with higher catch rates and more species (Table 1A–C, Table 2).

Preston's log normal estimate (76 species) came the closest to the total number of species that we captured (73 to species, and two additional species that could not be identified). The other methods, however, suggested as many as 57 additional species. It is quite likely that new species could be found by sampling different times of year, as well as different microhabitats across the island. Generally, the Chao 1 and Jackknife 1 methods are appropriate tests for estimating species richness (Gotelli and Colwell 2011; Samarasin *et al*. 2017) — in our case, 116 and 109 species respectively. These methods are based on the number of rare species, those with one or two individuals, and are not based on assuming an underlying distribution, whereas the log-normal method assumes that species abundance has a log-normal distribution, and that sampling is more or less unbiased. Any trap biases would have a larger effect on log-normal estimates. In our study, the estimates least affected by sampling bias were Jackknife 2 (132 species; Hortal *et al*. 2006) and Chao 2 (123 species; Colwell and Coddington 1994).

We found 55 new Nunavut species records, most of which were expected based on their current distributions in nearby jurisdictions (in Manitoba, Ontario, and Quebec). Akimiski Island is considerably farther south in relation to the Nunavut mainland, so while these records may be expected from the area because of its similar ecology to that of surrounding areas, they were not expected when compared with the rest of Nunavut. Jurisdictional boundaries can be important in conservation practice; in that regard, Akimiski Island is significant for Nunavut. It is the only island in Hudson Bay of that size without permanent residents, and has protections through the bird sanctuary on the eastern half of the island.

Table 1A represents expected species, found less than 400 km away from the nearest previous record. Most of these represent gap infills in their populations. Quite a few of these species, though not far enough to constitute range extensions by our criterion, were found at the edge of their species range. *Scaeva affinis* (Say) is quite common in western North America, with our record and a nearby record from the far north of Ontario representing the eastern-most points of its distribution. Although there is one southern Ontario record, it is presumed to be a vagrant (the species appears to be migratory in the west; Skevington, unpublished data).

Table 1B represents species with intermediate-sized gaps in distributions, which could be due to lack of sampling from the nearby regions. *Orthonevra robusta* (Shannon) is found largely in the western United States, and has a small disjunct population along the southern shores of Hudson Bay, which includes our record from Akimiski Island, as well as

one record from Churchill, Manitoba, and one from Fort Severn, Ontario.

Ten species were found more than 800 km away from previous records (Table 1C). *Cheilosia laevis* is found primarily in western North America towards the Pacific coast, with an outlying record on Anticosti Island towards the southeast of Quebec. *Eristalis hirta* is found primarily west of the Rocky Mountains, its their distribution also extends into the northern territories and eastward. The nearest records are in northern Manitoba and northern Quebec; the records from northern Manitoba are also within the Hudson Plains ecozone. *Platycheirus neoperpallidus* is a boreo-montane species, with the nearest records from southern Manitoba, to the west, and eastern Quebec, to the east. Our record falls midway between these two closest known localities. *Platycheirus nielseni* Vockeroth is found primarily in Yukon, and more sparsely distributed to the east, found in Nunavut, Newfoundland, Manitoba, and further south in Colorado. Each of these records represent gap infills for their respective populations.

The remaining six species from Table 1C all represent large range extensions. *Platycheirus kelloggi* and *Platycheirus latitarsis* Vockeroth represent eastern extensions of their populations. Both are known strictly west of the Rocky Mountains, which possibly act as an ecological barrier to their distribution. *Eumerus strigatus* (Fallén) and *Neocnemodon elongata* (Curran) represent northern range extensions. Both populations extend from the Pacific coast to the Atlantic coast along the border between the United States and Canada. *Eumerus strigatus* larvae tend to be associated with the bulbs of flowering plants, so this new record may have been associated with native bulb plants on Akimiski Island, although finding this species in an area devoid of horticulture might also suggest that it is a vagrant species (Blaney and Kotanen 2001; Kizil *et al.* 2008). *Pipiza atrata* Curran represents a northeastern range extension. It is a rare species, mostly found west of the Rocky Mountains, although it has been recorded from Minnesota and southern Ontario. *Platycheirus jaerensis* (Nielsen) is the only species representing a western range extension; it is found strictly along the east coast, ranging from Labrador to Maine.

The IPY traps caught a fairly high number of syrphids given the small trap size; they were composed mainly of two species: *Eristalis brousii* Williston (n = 34) and *Orthonevra robusta* (n = 32). They were caught in low numbers when IPY traps were not in use (2009–2017), though this difference in abundance is likely due to the difference in habitats where trapping took place. IPY traps were deployed along the shoreline, while all other trapping was done within camp, more inland towards the tree line. Both are species of interest. *O. robusta* was previously collected this far north only in Churchill, which is considerably disjunct from its western population in the United States. *Eristalis brousii* was once a common and widespread species whose range has since diminished and become restricted to northern latitudes, making it one of the most at-risk species of syrphid in North America (Skevington *et al.* in press). Since recognizing *E. brousii* in the IPY trap samples, we have collected two more specimens by hand netting, one in 2010 and one in 2013.

The other notable catches from the IPY were *Cheilosia lasiophthalmus* Williston, an uncommon species, our record being on the western edge of the eastern-most population, as well as *Platycheirus jaerensis*, an eastern, coastal species. The latter's appearance on Akimiski was unexpected, though the island is considered coastal and likely has the required habitat.

Akimiski Island is a low Arctic island that includes a mix of unique habitats, each

of which likely provides specialized microhabitats for many syrphid species. The landscape of Akimiski Island is a combination of Arctic-coastal and boreal forest, providing habitats for northern species and southern species. The placement and size of the island in James Bay could also be responsible for many large range extensions; insects transported by prevailing westerly winds would be deposited on the landscape when they encountered cold air over James Bay. As an island in James Bay, Akimiski has a maritime climate, with extreme temperatures moderated in comparison to continental landscapes on the adjacent mainland. This may provide a climate refuge for species normally found in more southern regions. Another feature unique to this island is the seasonal residence of abundant geese and shorebird populations. These have profound effects, denuding many areas of plants and changing plant community composition (Jefferies *et al*. 2006), with (we expect) similar effects on pollinator species such as syrphids. Insectivorous shorebirds rely on insects for food (Tulp *et al*. 2008; Bolduc *et al*. 2013), so the high number of shorebirds on Akimiski could also conceivably affect these insect populations.

In this paper, we reported on an interesting response to Nzi traps by species of the genus *Platycheirus*, *P. kelloggi* in particular. This study shows the continued importance and need of faunistic studies in remote regions. We have increased the number of known syrphid species from Nunavut, and reported several large range extensions, filling in much needed distributional information for flower flies in Canada's northern ecosystems. Perhaps most important in the long term, projects like these create a rich comparative dataset that will allow us to track population changes in response to changing environmental pressures and help us to discover and highlight habitats and species at risk.

Acknowledgements

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APPENDIX 1. Total syrphid catch from Malaise and Nzi traps, 2012–2017, Akimiski Island, Nunavut. Blanks represent zeros.

Species	Malaise	Nzi	Total
Anasimyia anausis	3		3
Cheilosia laevis	1		1
Cheilosia latrans	64	30	94
Cheilosia orilliensis		2	2
Cheilosia rita		1	1
Cheilosia shannoni	1		1
Chrysotoxum derivatum	5	2	7
Chrysotoxum flavifrons	2		2
Chrysotoxum plumeum	17	3	20
Dasysyrphus amalopis	1		1
Dasysyrphus limatus		1	1
Dasysyrphus venustus		1	1
Doros aequalis	1		1
Epistrophe nitidicollis	1		1
Epistrophella emarginata	1		1
Eristalis flavipes	1		1
Eupeodes confertus	2	1	3
Eupeodes curtus	1		1
Eupeodes flukei	3	3	6
Eupeodes luniger	1		1
Eupeodes perplexus		1	1
Ferdinandea buccata	3		3
Helophilus hybridus	1	1	2
Helophilus lapponicus	2		2
Helophilus obscurus	5		5
Lapposyrphus lapponicus	17	17	34
Melanostoma mellinum	56	14	70
Meligramma guttata	1		1
Meligramma trianguliferа	1		1
Meliscaeva cinctella	10	5	15
Neocnemodon elongata	1		1
Orthonevra robusta	9		9
Paragus haemorrhous	1		1
Parasyrphus genualis	1		1
Parhelophilus porcus	1	1	2
Pipiza atrata	1		1
Pipiza quadrimaculata	1		1
Platycheirus albimanus	4	1	5
Platycheirus amplus	1	2	3
Platycheirus clypeatus		1	1
Platycheirus granditarsis	1	2	3
Platycheirus hyperboreus	1		1
Platycheirus inversus	2		2
Platycheirus kelloggi	3	10	13
Platycheirus latitarsis		1	1
Platycheirus luteipennis		2	2
Platycheirus naso	2	1	3
Platycheirus neoperpallidus		3	3
Platycheirus nielseni	1		1
Platycheirus obscurus	2		2
Platycheirus pictipes	7	10	17
Platycheirus podagratus	2		2
Platycheirus varipes	1	3	4
Polydontomyia curvipes	1		1
Scaeva affinis	1		1
Sphaerophoria abbreviata		1	1
Sphaerophoria philanthus	12	1	13
Syrphus attenuatus	1		1
Syrphus ribesii	9		9
Syrphus sexmaculatus	2		2
Syrphus vitripennis	2		2
Volucella fascialis		1	1

FIRST RECORD OF *HARMOSTES FRATERCULUS* (SAY) (HEMIPTERA: RHOPALIDAE) IN CANADA

C. G. RATZLAFF

Vancouver, BC
email, chris.ratzlaff@gmail.com

Scientific Note *J. ent. Soc. Ont.* 150: 27–29

The hemipteran family Rhopalidae, commonly known as scentless plant bugs, is currently represented in Canada by 19 species in seven genera. It is most diverse in the west with 15 species recorded from British Columbia while only six have been recorded from Ontario (Maw *et al.* 2000; Scudder 2007, 2008; Roch 2017; Foottit *et al.* 2019). The genus *Harmostes* Burmeister is currently represented in Canada by two species, the widespread *Harmostes reflexulus* (Say) and the rare *Harmostes dorsalis* Burmeister, found only in British Columbia.

On 15 October 2017, during a short visit to Welland, Ontario, one specimen of *Harmostes* was taken off foliage while casually collecting in Merritt Island Park. This specimen was later identified as a female *Harmostes fraterculus* (Say) (Fig. 1A, B) and represents the first record of this species in Ontario and Canada.

Specimen Data: 1 ♀, CANADA, ON, Welland, Merritt Island Pk., 43.00542, -79.24005, 15.x.2017 (C.G. Ratzlaff) [specimen deposited in the Royal Ontario Museum, Toronto, Ontario, Accession # ROME 176935]

Harmostes fraterculus can easily be differentiated from the common *H. reflexulus* by the short first antennal segment, its length subequal to the apex of the head (Fig. 1A), and by the short buccula, which ends before the eyes (Fig. 1B). Göllner-Scheiding (1978), in the revision of *Harmostes*, provided excellent illustrations for both *H. fraterculus* (p. 277, Figs. 23–24) and *H. reflexulus* (p. 287, Fig. 46).

While not common, *H. fraterculus* has been recorded in the literature from much of the United States, Mexico, and Central America, with its range stretching from Guatemala north to Montana and Pennsylvania (Göllner-Scheiding 1978; Henry and Froeschner 1988). Provancher (1886) originally recorded this species from Canada, a statement reiterated by Göllner-Scheiding (1978), but according to Van Duzee (1912) the specimen Provancher originally reported on was actually a misidentified individual of *Neortholomus scolopax* (Say) (Hemiptera: Lygaeidae).

The majority of the field biology known about *H. fraterculus* is based on studies of two populations in Pennsylvania from 1978 to 1981 by Wheeler and Miller (1983). They hypothesized that in the northern extent of its range, *H. fraterculus* is not a permanent resident but rather a late-season migrant, with adults only appearing from September to

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November. However, colonization and overwintering may occur if suitable host plants are found. Several of those potential host plants, including members of the genera *Ambrosia* L. and *Eupatorium* L. (Asteraceae), are quite widespread in southern Ontario. Additionally, there have been recent online photographic records of *H. fraterculus* from Massachusetts, New York, Rhode Island, and Vermont (Bugguide; iNaturalist), indicating that this species is being found further north than officially reported. The specimen collected in Welland may be a result of a northward migration from New York, but the presence of a permanent population of *H. fraterculus* in southern Ontario would not be surprising. Further sampling at several times of the year would determine whether this species is now a permanent resident or just a migrant.

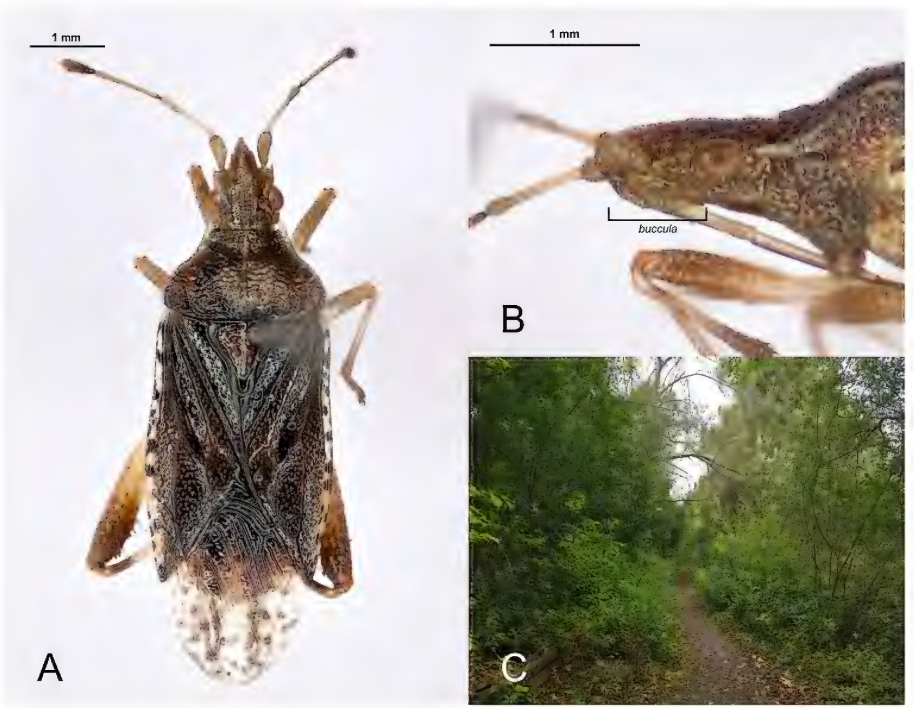

FIGURE 1: (A) Female *Harmostes fraterculus* (Say) from Welland, Ontario, (B) Lateral view of *H. fraterculus* head showing the short buccula, (C) Example of forested habitat in Merritt Island Park, Welland, Ontario where *H. fraterculus* was found.

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FIRST CANADIAN RECORD OF THE ZOOPHILIC FRUIT FLY *PHORTICA VARIEGATA* (FALLÉN) (DIPTERA: DROSOPHILIDAE)

M. MILLER[1*], S. A. HILL[2], B. J. SINCLAIR[3]

University of Guelph, 50 Stone Rd E, Guelph, ON, Canada, N1G 2W1
email, meredithellenmiller@gmail.com

Scientific Note *J. ent. Soc. Ont.* 150: 31–36

The large cosmopolitan family Drosophilidae (Diptera) (vinegar flies) contains over 4,000 species and is very well-known for its extensive use in biological research. The family is divided into two subfamilies, Drosophilinae (43 genera) and Steganinae (28 genera), in addition to two genera *incertae* sedis within Drosophilidae (Brake and Bächli 2008). Within the subfamily Steganinae, nine genera have been recorded in the Nearctic Region, five of which are found in Canada (Brake and Bächli 2008). Feeding habits of the Steganinae are highly diverse, with the ecology of many genera much less known than those in Drosophilinae, which typically feed on plant materials or fungi (Baechli *et al.* 2004).

Phortica Schiner in the subfamily Steganinae is composed of over 97 species found largely in the Oriental and Palearctic regions (Brake and Bächli 2008; Cheng *et al.* 2008). Prior to 2014, four species of *Phortica* had been reported in the Nearctic Region: *P. albavictoria* (Patterson & Mainland) from Mexico, *P. huachucae* (Wheeler) from Arizona, *P. picta* (Coquillett) from Mexico to Nevada, and *P. polychaeta* (Wheeler) from northern Mexico and the southwestern United States. All four species are native to the Nearctic Region (Brake and Bächli 2008; D. Grimaldi, American Museum of Natural History, pers. comm., March 7, 2018). In 2014, *P. variegata* (Fallén) (Figs. 1A–D), the zoophilic fruit fly, was discovered in Orange County, New York State by D. Grimaldi; the following year, this introduced species was reported from Monroe County, New York State (Werner and Jaenike 2017; Grimaldi 2018). Images posted on the online resource BugGuide (https://bugguide.net) from Middlesex County, Massachusetts (Murray 2011) and identified as *P. variegata* date back to 2011. Therefore, the introduction of this species into the United States was at least as early as 2011.

Phortica variegata is native to the Palearctic Region and, as its common name suggests, males of the zoophilic fruit fly are attracted to lachrymal secretions of humans and other animals (Otranto *et al.* 2006a). The biology of this species is little known; however,

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* Author to whom all correspondence should be addressed.
[2] Mississauga, ON, Canada
[3] Canadian National Collection of Insects and Ottawa Plant Laboratory - Entomology, CFIA, K.W. Neatby Bldg., C.E.F., 960 Carling Ave., Ottawa, ON, Canada K1A 0C6

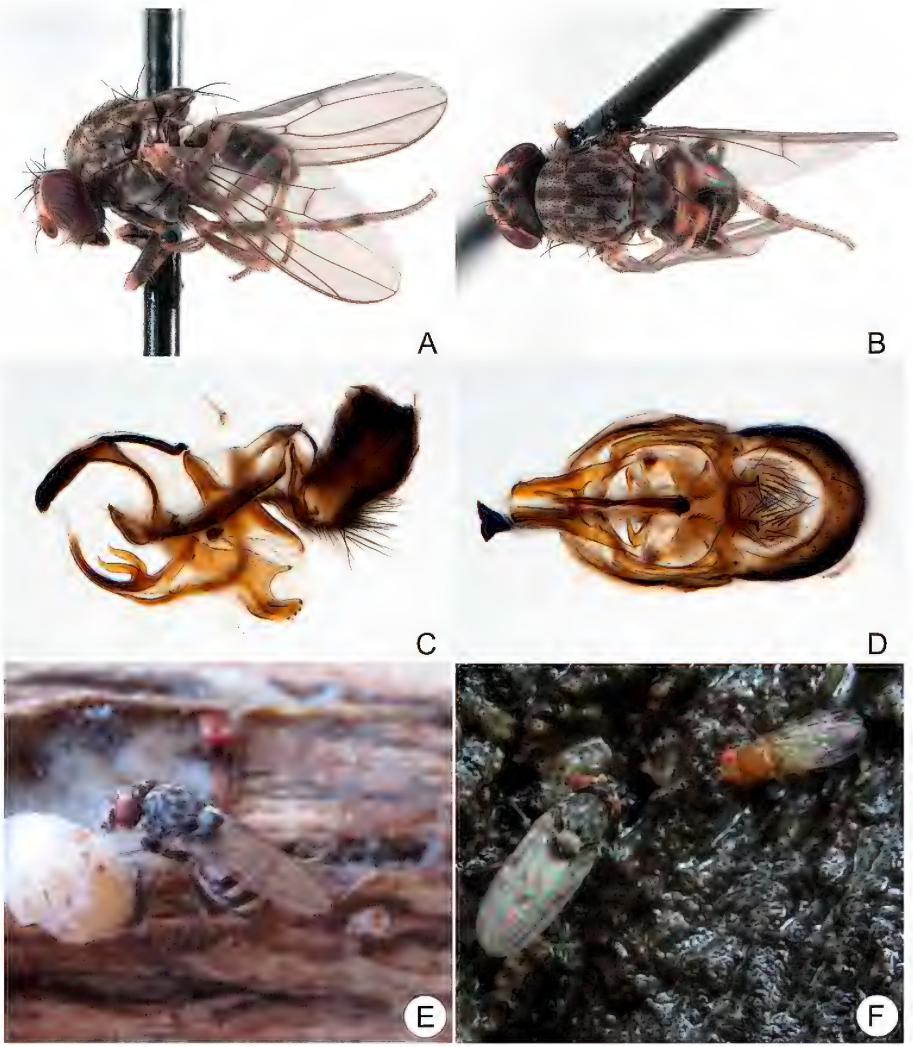

FIGURE 1. *Phortica variegata* (Fallén): (A) Male habitus, lateral view; (B) Male habitus, dorsal view; (C) Male terminalia, lateral view; (D) Male terminalia, ventral view; (E) Female feeding on *Lonicera* sp.; (F) Specimen (left) feeding at sap flow on *Quercus* sp. along with specimen of *Drosophila* sp. (right).

adults have been collected at apple, pear, and mushroom baits, and larvae have been observed feeding on the sap of weeping willows (Werner and Jaenike 2017).

Here we present the first records of the genus *Phortica* and the species *P. variegata* in Canada. Two adult specimens were discovered by S. Hill in October 2017, during an entomological survey of Riverwood, an urban park in Mississauga, Ontario. Additional specimens were collected during the summer of 2018 at the same location (Appendix). Flies were observed in relatively low abundance on the woody tissue of oak (*Quercus* L. sp.) and non-native honeysuckle (*Lonicera* L. sp.), where they were feeding at sap flows (Fig. 1E, F). On multiple occasions at Riverwood, S. Hill noted adults flying towards and subsequently hovering just in front of her face, behaviour presumably associated with the flies' attraction to ocular fluids.

One female specimen was submitted to the Centre for Biodiversity Genomics (CBG) at the University of Guelph for DNA barcoding through the LifeScanner Program (Hebert *et al*. 2003). This specimen (Sample ID: BOLD-0FHD3KBZ2) was assigned to the genus *Phortica* by the automated identification engine of the Barcode of Life Data System (BOLD) (Ratnasingham and Hebert 2007). Upon examination of specimen images by D. Grimaldi, S. Hill, J. Jaenike, S.A. Marshall and T. Werner, and through morphological identification by M. Miller, and morphological identification/genitalic dissections of material collected in June 2018 (2 females, 2 males) by B. Sinclair, specimens were identified as *P. variegata*. The taxonomy of the sequenced specimen (Sample ID: BOLD-0FHD3KBZ2) was subsequently updated to reflect this species-level designation on BOLD, and all identified samples were deposited into the Canadian National Collection of Insects in Ottawa, Ontario (CNC). Two additional specimens were submitted through the LifeScanner Program (Hebert *et al*. 2003) to CBG for DNA sequencing; these specimens (Sample IDs: BOLD-3MR8KSYX0 & BOLD-3MQP8FJ09), collected in July 2018, were both identified as *P. variegata* by the BOLD automated identification engine (Ratnasingham and Hebert 2007) and the generated sequences matched Sample ID: BOLD-0FHD3KBZ2 with 100% similarity. Each of the three sequenced specimens were assigned to Barcode Index Number (BIN) BOLD:ADP2209 (Ratnasingham and Hebert 2013), which also included one additional *P. variegata* record, collected in Germany.

Phortica variegata is a robust, dark to light brown drosophilid measuring 3.5 to 5 mm in length (Otranto *et al*. 2006a). In both sexes, the scutum is greyish, with a pattern of large, dark greyish spots, and eight irregular rows of acrostichal setae (Fig. 1A, B). The wing is hyaline, with clouding at the posterior crossvein (dm-m). The coxae and femora of males are dark, with a yellow base at the apex of each femur, and the tibia of each leg bears three conspicuous dark bands. The abdominal tergites are pale, with dark pigmentation along the midline. In northeastern North America, *P. variegata* may be superficially confused with *Drosophila repleta* Wollaston or *D. hydei* Sturtevant, both of which exhibit a pattern of dark grey spots on the scutum with eight rows of acrostichal setae; however, the dark spots on the scuta of these species are smaller (present around the bases of the setae and setulae), when compared to those of *P. variegata.* Furthermore, both species of *Drosophila* species lack conspicuous dark tibial bands and, unlike *P. variegata*, bear dark bands on the abdominal tergites that are broken at the midline (see images in Miller *et al*. 2017).

Male *P. variegata* are known to be intermediate hosts and vectors of the parasitic nematode *Thelazia callipaeda* Railliet & Henry (Nematoda: Spirurida: Thelaziidae),

which causes the zoonotic disease Human Thelaziasis (Wang *et al.* 2002; Otranto *et al.* 2005; Otranto *et al.* 2006b; Máca and Otranto 2014; Werner and Jaenike 2017). Male flies transport larval *T. callipaeda* in their proboscis from one host to another, as they feed on the lachrymal secretions of the host's eyes (Otranto *et al.* 2006b). *Thelazia callipaeda* nematodes live within the eyelid or nictitating membrane of the eye, also feeding on tear duct secretions (Werner and Jaenike 2017). Thelaziasis affects many mammals including dogs, cats and humans, with clinical symptoms ranging from discharge from and watering of the eye to conjunctivitis and keratitis (Otranto *et al.* 2013).

The spread of *P. variegata* into new geographic regions may accompany an increased risk of *T. callipaeda* infection to humans and other animals within those regions, with concomitant implications for both the human healthcare and veterinary sectors (Marino *et al.* 2018). Other species within *Phortica* may also serve as vectors of the eye worm *T. callipaeda* (Cantacessi *et al.* 2008); these potential vector species include *P. okadai* (Máca) (Wang *et al.* 2002; Otranto *et al.* 2005) found in Russia, Korea, China and Japan (Brake and Bächli 2008), and *P. semivirgo* (Máca) found in Europe (Cantacessi *et al.* 2008). While the latter is morphologically similar to *P. variegata*, differences both in the male terminalia and in the colouration of the gena (pale in *P. semivirgo* and brownish in *P. variegata*) distinguish each species. Continued monitoring for all potential vector species is warranted to help mitigate the potential health threats if population levels of these flies increase.

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APPENDIX 1.

Material examined. ONTARIO: Mississauga, Riverwood Park, 18.x.2017, 43.56582, -79.6793, S. Hill (1♀, CNC); same locality, 25 & 29.vi.2018, S. Hill (2♀, 2♂, CNC); same locality, 6 & 17.vii.2018, S. Hill (2 unsexed specimens, CBG).

DOES IT MAKE SCENTS? A CASE FOR THE EXTIRPATION, AND POSSIBLE EXTINCTION, OF THE NATIVE STINK BUG *RHACOGNATHUS AMERICANUS* (PENTATOMIDAE: ASOPINAE)

S. M. PAIERO

School of Environmental Sciences, University of Guelph,
Guelph, Ontario, Canada N1G 2W1
email, paieros@uoguelph.ca

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The known natural history and distribution of the native stink bug *Rhacognathus americanus* (Stål) and its disappearance in North America are reviewed. Direct and indirect sampling efforts to document its occurrence are discussed, and a case to consider it locally extirpated from southern Ontario, and perhaps its possible extinction, is made.

Introduction

Rhacognathus americanus (Stål, 1890) is a large predaceous stink bug (Pentatomidae: Asopinae) (Fig. 1) native to North America, and is recorded from the Northwest Territories to New Jersey, south into Indiana and Nebraska (Maw et al. 2000, Froeschner 1988). A recent review of the Ontario Pentatomidae (Paiero et al. 2013) noted that this species, despite its relatively large size (9–11 mm), has not been documented in Ontario since 1962. Although several other recent reviews of regional pentatomid faunas in the U.S.A. have suggested that *R. americanus* should be found in their respective states (Rider 2012; O'Donnell and Schaefer 2012), there is an absence of any recent material. To fully document the known distribution and natural history of this species, the available literature and specimen records are provided, and the possibility that *R. americanus* has become regionally extirpated, if not extinct, is discussed.

Materials and methods

The literature and regional insect collections within the known distribution of *R. americanus* were examined to accumulate all known records for *R. americanus*. The major collections within the known distribution of *R. americanus* were contacted as these collections were the most likely to have locally collected material. Collections contacted,

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including those with online specimen holdings, include (listed alphabetically): Academy of Natural Sciences (Philadelphia, Pennsylvania); Albert J. Cook Arthropod Research Collection, Michigan State University (East Lansing, Michigan); American Museum of Natural History (New York, New York); Canadian National Collection of Insects (Ottawa, Ontario); Cornell University Insect Collection (Ithaca, New York); Field Museum of Natural History (Chicago, Illinois); Frost Entomological Museum (State College, Pennsylvania); Great Lakes Forestry Centre (Sault St. Marie, Ontario); Lethbridge Research and Development Centre collection (Lethbridge, Alberta); Lyman Entomological Museum (Ste-Anne-de-Bellevue, Quebec); Montreal Insectarium (Montreal, Quebec); North Dakota State Insect Reference Collection (Fargo, North Dakota); Northern Forestry Insect Collection (Edmonton, Alberta); Purdue Entomological Research Collection (West Lafayette, Indiana); Royal Alberta Museum (Edmonton, Alberta); Royal Ontario Museum (Toronto, Ontario); Royal Saskatchewan Museum (Regina, Saskatchewan); Triplehorn Insect Collection, Ohio State University (Colombus, Ohio); United States National Museum (Washington, D.C.); University of Delaware Insect Collection (Newark, Delaware); University of Guelph Insect Collection (Guelph, Ontario); University of Minnesota Insect Collection (St. Paul, Minnesota); University of Michigan Museum of Zoology (Ann Arbor, Michigan); Wallis-Roughley Museum of Entomology (Winnipeg, Manitoba). Global Biodiversity Information Facility (https://www.gbif.org), iNaturalist (https://inaturalist.ca), the Barcode Of Life Database (http://www.boldsystems.org/) and BugGuide (https://bugguide.net) were also examined for possible unpublished records. Full specimen data are available from Paiero (2018).

FIGURE 1. Habitus of *Rhacognathus americanus* (Stål) (dorsal, left; ventral, right). The left antenna is missing the apical segment.

Occurrence

A total of 39 unique collection records of *R. americanus* were compiled (Paiero 2018) from available specimen data and those noted in the literature (Stål 1870; Uhler 1876; Osborn 1901; Van Duzee 1904; Parshley 1917; Hart 1919; Stoner 1921; Hussey 1922; Blatchley 1926; Steyskal 1938; Furth 1974; McPherson 1982; Roch 2008). Localities and collections were georeferenced using Google Earth and mapped (Fig. 2) using SimpleMappr (Shorthouse 2010). Vague localities or broad geographic regions were excluded from the map (e.g., "Northern Illinois") and county-based localities were only included (as a central record) if there was no other locality within that county. The global Index of Area of Occupancy (112 km^2) and Extent of Occurrence (3,146,006 km^2) were calculated from GeoCat (Bachman et al. 2011) based on locality data provided in Paiero (2018), including the Quebec record, for future consideration.

Results and discussion

Distribution and habitat

With the exception of one specimen, there are no confirmed records of this species (specimen or photo) anywhere from the past 50 years. The only 'modern' record of *R. americanus* was recorded in Quebec (Roch 2008; Entomofaune de Quebec Inc. 2019) and is based on correspondence regarding a single specimen that was deposited in a private collection. This collection was later deposited, in part, at several collections, including the Canadian National Collection (Ottawa, Ontario) and the Montreal Insectarium (Montreal,

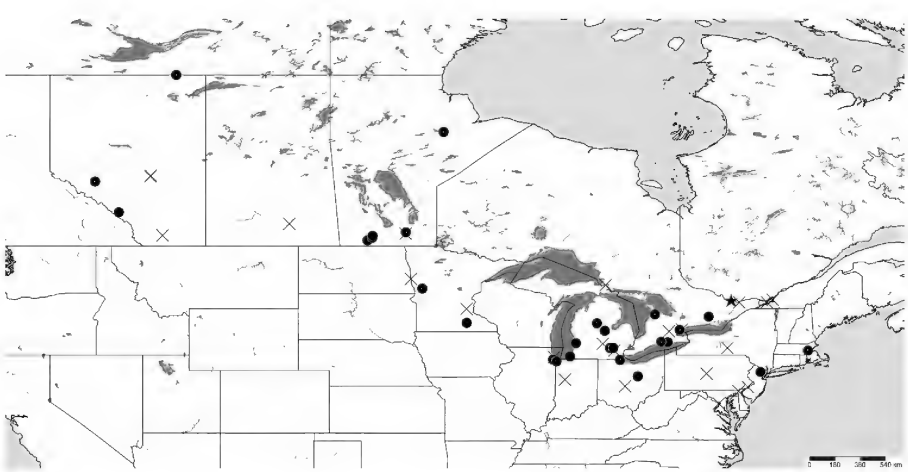

FIGURE 2. Historical distribution of *Rhacognathus americanus* (Stål). Circles represent localities from before 1966, the star represents the Quyon, QC, specimen, and crosses represent contacted regional and major collections.

Quebec), but some material may have been lost when the collectors' private residence was damaged by fire. At present, no specimens of *R. americanus* can be found at either collection, and it may have been a misidentified specimen of another genus. With no means of confirming the identity of this specimen, this is treated as a dubious record, making the most recent record of *R. americanus* from 1966 in Manitoba.

Very little is known about the natural history of *R. americanus* besides what can be inferred from label data and the few published accounts. The adult flight period ranges from 23 May to 17 August. A predaceous stink bug (Asopinae), this species likely feeds on a variety of other insects but has only been documented "sucking on a *Lina sp.*", which may have been a misidentification of a *Plagiodera versicolora* Laicharting, 1781 (Coleoptera: Chrysomelidae). Four *R. americanus* specimens were collected in wetland/grassland communities (dunes, marshes, beaches and spruce-sand communities; Paiero 2018), which is consistent with its European congener, *R. punctatus* (Linnaeus, 1758). *Rhacognathus punctatus* (also known as the heather bug) has been recorded from "high quality wetlands" in Wales (Ramsay 2013), dry heaths (Hawkins 2003), from moss in heaths (Roche 1965), and "heathland and moorland, although occasionally recorded from dune slacks and commons in the absence of *Calluna* [Ericaceae]*"* in the United Kingdom (Bantock and Botting 2013). Like *R. americanus*, *R. punctatus* is apparently widely distributed but is "always scarce and found at low densities" (Bantock and Botting 2013). Peiricart (2010) suggested *R. punctatus* feeds only on chrysomelid larvae.

Collection effort

While there have been no large scale directed efforts to find *R. americanus*, several recent projects and efforts may have indirectly sampled for it, including specimen-based studies and photo vouchers. The most important efforts to document *R. americanus* are the various regional reviews of the stink bug fauna. These reviews identified and re-examined specimen records collected from the area and provided updated keys, distributions, and checklists. A number of reviews of the stink bug fauna in the past decade (O'Donnell and Schaefer 2012; Rider 2012; Swanson 2012; Paiero et al. 2013; Koch et al. 2014) found no new collections of *R. americanus*, with the exception of Roch (2008). BugGuide and iNaturalist websites also lack any recent records for *R. americanus* despite the proliferation of contributors to both sites. *Rhacognathus americanus* is a relatively large stink bug well within the size range for even basic photography systems, but only an image of a single historical specimen is available (see bugguide.net/node/view/716152 and bugguide.net/node/view/716154). While it could be argued that its cryptic appearance makes it less likely to be encountered, other similarly sized and coloured stink bug species in the genus *Brochymena* Amyot and Audinet-Serville, 1843 are arguably more cryptic but are represented by at least 1,064 photographs on BugGuide and 2,275 records on iNaturalist in North America (as of 22 June 2019).

The extensive efforts throughout the United States and Canada to document the spread of *Halyomorpha halys* (Stål, 1855) (the brown marmorated stink bug) (e.g., Leskey et al. 2012; Gariepy et al. 2014) were never meant to sample for *R. americanus*, but similar off-target brown stink bugs were collected, and it would seem likely that *R. americanus* would have been collected if it were encountered. *Rhacognathus americanus* is superficially similar to *H. halys* with general colouration, pale bands on the tibiae, alternating dark-light

markings on the connexivum, and smooth anterolateral pronotal margins, although it is slightly smaller in size than *H. halys* (9–11 mm versus 12–17 mm, respectively). Although the two species are thought to occur in different habitats, the raised interest in *H. halys* still increased sampling for stink bugs and no additional records have emerged.

Insect surveys and 'bioblitzes' are sampling efforts that were also considered in regards to search effort for *R. americanus*. Several funded terrestrial insect surveys in southern Ontario sites by personnel at the University of Guelph Insect Collection, including several with wetland and grassland habitat (e.g., Blades and Marshall 1994, Paiero et al. 2008), extensively sampled the fauna (with a sampling bias towards Hemiptera due to interest of some of the personnel). Opportunistic efforts were also made to document the provincial bug fauna at other sites in southern Ontario, with an interest in relocating this species. Various 'bioblitzes', including several at sites with both wetlands and grasslands such as Point Pelee National Park, Credit River watershed and Ojibway Prairie Provincial Nature Reserve, have also taken place in southern Ontario and include both specimens and photo vouchers posted on iNaturalist. The Barcode Institute of Ontario's Malaise and 'BioBus' sampling programs have sampled over 1 million specimens from Ontario Parks and 755,000 from Canadian National Parks (Centre for Biodiversity Genomics 2017), with partial cytochrome c oxidase subunit 1 (CO1) sequences for *R. americanus* and a BIN for *R. punctatus* (BOLD:ABU5656) on file for comparison. All of these efforts have failed to document a single *R. americanus*, despite relatively large insects such as stink bugs usually being conspicuous targets for both naturalists and entomologists.

Conclusion

There are other cases of relatively large insects that have been reported as extirpated in Ontario (including butterflies, lacewings and beetles), and there are also several that have since been relocated. The spider wasp *Ceropales bipunctata* Say, 1824 (Hymenoptera: Pompilidae) was considered extirpated by the absence of records in the previous 45 years (Godsoe 2003), but this was explained by a lack of directed collecting effort for spider wasps, with recent collections in Ontario establishing its presence and providing insight into why it was previously overlooked (Klymko et al. 2017). McCorquodale et al. (2007) listed 20 long-horned beetles (Coleoptera: Cerambycidae) that had not been collected in Ontario since 1950, but they noted that this may be an artifact of diminished sampling effort and not actually represent disappearances; at least two of these species have since been recollected in Ontario. For *R. americanus*, there has been substantial sampling effort, both direct and indirect, that indicates it is no longer in Ontario. The scattered historical records from throughout the range of *R. americanus* suggests that it was already a rarely encountered species. Even so, the absence of any record in the past 52 years suggests that, at the very least, it has declined in parts of its range, especially southern Ontario. The general interest in stink bugs by amateur and professional entomologists suggests that at least one specimen would have been found and recognized over the past few decades if it was still present, especially given the increased sampling efforts in the past two decades. The availability of taxonomic keys, proliferation of online postings, and regional reviews continue to draw interest to this group, but still no modern records have emerged. Although very little about its natural history is known, what can be drawn from historical material and

associations of congeners suggests that *R. americanus* should be found in various wetlands and grasslands. No specific cause for its apparent decline is known, but potential causes for the decline of other Ontario species include light pollution (Marshall 1996), decline in quality and quantity of habitat or resources (Packer 1994; Marshall 1996; Sikes and Raithel 2002; McCorquodale et al. 2007; Colla and Dumesh 2010), and the introduction of predators or parasites (Wagner 2012; Harmon et al. 2007). Despite the lack of any evidence that shows that it still persists, at least at the provincial level, it is hoped that *R. americanus* might still be found in small localized pockets of specific habitat (such as bogs), or in northern parts of Ontario and the prairies where active sampling efforts are comparatively limited, and that this study will inspire increased efforts to relocate it.

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GOING OFF THE DEEP END: USING PUBLIC OUTDOOR SWIMMING POOLS AS A DETECTION SURVEY TOOL FOR INVASIVE INSECTS

E. BULLAS-APPLETON[1*], T. KIMOTO[2], G. S. THURSTON[3], A. SLATER[3], A. KISS[1] AND I. NEI[3]

Canadian Food Inspection Agency,
174 Stone Road West, Guelph, ON, N1G 4S9, Canada
email, erin.bullas-appleton@canada.ca

Abstract

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In 2017, the Canadian Food Inspection Agency analyzed the contents of outdoor swimming pool filters in Essex County to determine if pools could be used to detect invasive insects. Insects from two orders and nine families were collected, with Scarabaeidae (Coleoptera) being the most numerous taxon. In addition to Japanese beetle (*Popillia japonica* Newman), we caught scooped scarab (*Onthophagus hecate* (Panzer)), European chafer (*Amphimallon majale* (Razoumowsky)), Asiatic garden beetle (*Maladera castanea* (Arrow)), northern masked chafer (*Cyclocephala borealis* Arrow) and southern masked chafer (*C. lurida* Bland) in the filters. Of these, *M. castanea* is a new record for Ontario, while *C. borealis* is a new Canadian record. In total, 74 scarab beetles were captured in the filters and all of them were in good condition to allow for morphological identification. These results show that examining the contents of pool filters shows promise as a detection tool for non-indigenous insects.

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Introduction

The Canadian Food Inspection Agency (CFIA) is responsible for safeguarding food, animals and plants in Canada. The CFIA and its partners mitigate the risks to Canada's plant resource base through the development and delivery of surveillance activities designed to detect and delimit invasive plant pests. These surveys include both general and pest-specific tactics including semiochemical-baited traps, rearing insects from trees occurring in high risk areas and ground-based visual surveys (Bullas-Appleton *et al.* 2014).

* Author to whom all correspondence should be addressed.
[2] Canadian Food Inspection Agency, 4321 Still Creek Drive, Burnaby, BC, V5C 6S7, Canada
[3] Canadian Food Inspection Agency, 960 Carling Avenue, Bldg 18, Ottawa, ON, K1A 0Y9, Canada

The CFIA's Plant Health Surveillance Unit (PHSU) designs new surveys and supports the development of novel tools and techniques to increase the efficiency and effectiveness of plant pest surveys. Through the implementation and evaluation of pilot projects, the PHSU assesses survey methods that may be adopted operationally to enhance and improve detection sensitivity. For example, the PHSU has recently tested whether commercially available unmanned aerial vehicles could detect simulated signs of damage caused by Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (Coleoptera: Cerambycidae) (Bullas-Appleton *et al.* unpublished; Kimoto *et al.* unpublished). When considering the ease and effectiveness of using pan traps to sample insects inexpensively (Campbell and Hanula 2007) and our experience of noticing insects either floating on top of water or gathered in pool filters, we decided to conduct a survey of outdoor pools to see if they could be used to detect non-indigenous plant pests. Brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), and Asian longhorned beetle are two insect species not indigenous to North America that have been collected in outdoor pool filters (USDA 2010), indicating that this may be a potential detection tool that can also promote invasive species public awareness.

The following pilot project was intended to 1) determine which insect taxa are intercepted in public outdoor swimming pools, 2) assess the condition and capacity for morphological identification of specimens intercepted in pool filters and 3) determine operational potential for this type of survey.

Materials and Methods

Samples were collected from 01 June to 31 August 2017, in Essex County, Ontario. Large plastic containers were left with staff at six outdoor public pools in Windsor and at each of the outdoor pools in the towns of Tecumseh and LaSalle (Fig. 1). All pools have an indoor filtration system involving diatomaceous earth or sand in addition to either external grates, skimmer baskets or hand-held skimmers that complement the internal filters. Pool debris intercepted by these filtration systems was placed in plastic containers by the pool staff. As it was quite disruptive to ask staff to empty the filters on a regular basis, allowing them to fill the plastic containers on their schedule enabled their cooperation in this project. These containers were picked up by CFIA from each pool weekly or every other week, and brought back to the office where insects were carefully removed from pool debris. Initially, the targeted insects were wood boring beetles in the families Cerambycidae, Buprestidae, Curculionidae (primarily Scolytinae) and sap beetles (Nitidulidae), the latter being vectors of oak wilt, *Bretziella fagacearum* (Bretz). However, upon sorting the first samples, it was evident that taxa other than the target insects were present. From that point onward only the hard-bodied insects were placed into vials with 75% non-denatured ethanol and sent to CFIA's entomology laboratory for identification. Only specimens in adequate morphological condition were identified. Non-target taxa, such as dragonflies, earwigs, spiders, moths, flies, etc. were discarded and not identified. Entomologists from Agriculture and Agri-Food Canada and the Canadian Museum of Nature (Ottawa, Ontario) provided verification of the identifications done by CFIA's entomology laboratory.

FIGURE 1. Location of outdoor public swimming pools in Windsor, LaSalle and Tecumseh, Ontario used in the survey.

Results and Discussion

Insects from two orders and nine families were sent for further identification. By far, Scarabaeidae (Coleoptera) was the most numerous taxon captured and included the following species: Asiatic garden beetle, *Maladera castanea* (Arrow), northern masked chafer, *Cyclocephala borealis* Arrow, southern masked chafer, *C. lurida* Bland, scooped scarab, *Onthophagus hecate* (Panzer), European chafer, *Amphimallon majale* (Razoumowsky) and Japanese beetle, *Popillia japonica* Newman (Table 1). *Maladera castanea* is a new record for Ontario while *C. borealis* represents a new Canadian and provincial record (Bousquet *et al.* 2013). Although *C. lurida* has been collected from Rondeau Provincial Park (Ratcliffe and Cave 2017), this is only the second record for Ontario. The lone *C. borealis* specimen is archived at the CFIA Ontario Plant Laboratory (Entomology), Central Experimental Farm, Ottawa, Ontario. Two *M. castanea* (CNC 312509, CNC 312510) and three *C. lurida* (CNC 1174733) specimens have been deposited at the Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa, Ontario. *Maladera castanea* is native to temperate East Asia, but now occurs throughout most of northeastern North America including Quebec and Nova Scotia (Bostanian *et al.* 2003; Chantal 2003; Cutler and Rogers 2009; Löbl and Löbl

2016; Klimaszewski *et al.* 2017). Twenty-six percent of all scarabs were *M. castanea* and were collected from LaSalle and all six Windsor pools, suggesting that it has probably been established in Essex County for some time. This beetle is considered a minor pest whose populations can increase to levels such that they occasionally cause economic damage to turf, field crops, and gardens (Cutler and Rogers 2009). *Cyclocephala borealis* and *C. lurida* are indigenous to the eastern US but the former had previously not been found in Canada and the latter is a second record for Ontario (Bousquet *et al.* 2013; Gyawaly *et al.* 2016). One *C. borealis* was collected from Central Pool in Windsor and six *C. lurida* specimens were collected from the pool in LaSalle (Table 1). Similar to Japanese beetles, *C. borealis* and *C. lurida* larvae feed on grass roots and can be turfgrass pests in the US (Gyawaly *et al.* 2016). *Onthophagus hecate* is native to Canada while *A. majale* was introduced from Europe and has occurred in Ontario since the 1960s (Turner 1964; Klimaszewski *et al.* 2017). The latter can cause serious damage to lawns and turf in Canada and the US (Simard *et al.* 2001). Although *A. majale* has occurred in Ontario for many decades, only three specimens were collected, each from a different pool, suggesting that populations may have been low in 2017 or this survey technique is not appropriate for this species. *Popillia japonica* occurred in all eight pools and was the most common scarab, representing 59% (44 of 74 specimens) of the collection. This beetle is native to Japan and was discovered in New Jersey in 1916 (Potter and Held 2002). It now occurs in eastern Canada, ranging from Ontario to Nova Scotia, as well as central and eastern USA (Potter and Held 2002; Bousquet *et al.* 2013; Klimaszewski *et al.* 2017). Additionally, 19 carabids and one *Neandra brunnea* (Fabricius) (Coleoptera: Cerambycidae) were also collected. The families Dytiscidae, Elateridae, Lampyridae, Rhopalidae and Notonectidae were also found in the filters but these were not identified to species because they are not plant pests and were not targeted in this survey.

Only six pentatomids were captured in filters (Table 2), including two specimens of brown marmorated stink bug, *Halyomorpha halys* (one at the Riverside Centennial pool and the other at the Lasalle pool). This finding suggests pools are not an effective sampling tool for Pentatomidae.

The 74 scarab and 19 carabid beetles collected from pools were all in very good condition, which allowed for morphological identification. Some showed slight signs of decay but this did not affect key features.

TABLE 1: Number of scarab beetles (Coleoptera: Scarabaeidae) collected from pools in Essex County, Ontario in 2017.

Pool	*Amphimallon majale*	*Cyclocephala borealis*	*Cyclocephala lurida*	*Maladera castanea*	*Onthophagus hecate*	*Popillia japonica*
Atkinson	0	0	0	1	0	1
Central	0	1	0	3	0	5
Lanspeary	0	0	0	1	0	3
Mic Mac	1	0	0	6	0	9
Remington	1	0	0	6	1	4
Riverside Centennial	0	0	0	1	0	4
Tecumseh	0	0	0	0	0	7
LaSalle	1	0	6	1	0	11
Total	3	1	6	19	1	44

TABLE 2: Number of pentatomids (Hemiptera: Pentatomidae) collected from each pool in Essex County, Ontario in 2017.

Pool	*Halyomorpha halys*	*Euschistus* sp.	*Holcostethus* sp.
Atkinson	0	0	0
Central	0	1	1
Lanspeary	0	0	0
Mic Mac	0	0	0
Remington	0	1	0
Riverside Centennial	1	1	0
Tecumseh	0	0	0
LaSalle	1	0	0
Total	2	3	1

The new provincial and Canadian records are a positive proof of concept of this survey. However, it is unclear how effective outdoor public swimming pools are at detecting new species because we did not have enough time or resources to assess the population of captured insects within the surrounding environment. Future research should try to determine if the catch rate is comparable to survey methods that deploy traps or involve visual examination. Such projects could also assess how abundance in the environment affects pool catch rate. Targeting pools that have lights turned on at night, as well as sampling immediately after strong winds, could also be examined in future studies as these will impact the diversity and quantity of species collected. One limiting factor when considering using outdoor public swimming pools as a detection survey tool is their restricted geographical distribution. Alternatively, assessing the filter contents of residential outdoor pools in areas where these are common may provide interesting results (e.g. Quebec has some of the highest concentrations of outdoor pools in North America according to Perreaux 2012). Inviting citizens to participate in invasive species surveys has many benefits, such as increasing the probability of discovering a previously unreported species and contributing to the distribution of established species. Furthermore, datasets generated from such projects have the potential to advance scientific knowledge and enhance survey capacity, influence policy and guide resource management (Kosmala *et al.* 2016).

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POSTER AND PRESENTATION ABSTRACTS ENTOMOLOGICAL SOCIETY OF ONTARIO ANNUAL GENERAL MEETING

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Poster abstracts

Can honeybees detoxify neonicotinoids?
S. Bahia*, N. Tsevtkov, A. Khalil, and A. Zayed.
**sbahi035@yorku.ca*

Canadian honeybees have experienced high colony mortality in recent years with neonicotinoid usage on crops being a major contributing factor. Honey bees tend to be more sensitive to N-nitro neonicotinoids (imadocloprid, clothianidin, thiamethoxam) compared to the N-cyano class (thiacloprid) due to the latter being more easily metabolized by the honeybee. Here we examine if honey bees that survive exposure to the N-nitro neonicotinoid clothianidin have different levels of expression of specific detoxification enzymes (e.g. CYP9Q1-3, a family of cytochrome p450 monooxygenases responsible for metabolizing neonicotinoids) relative to honey bees that die after exposure to clothanidin.

Where did the honey bee come from?
K. Dogantzis*, T. Tiwari, I. Conflitti, A. Dey, and A. Zayed.
**kdogantzis@gmail.com*

The honey bee, *Apis mellifera*, is natively distributed through Africa, Europe, and parts of Asia. Though it is commonly agreed that subspecies can be divided into at least five genetically distinct evolutionary lineages, there remains considerable contention regarding the species ancestral origin and subsequent expansion across its native range. Addressing this question is important for understanding how the honey bee genome diverged to facilitate adaptation across its distribution. Here, we used an extensive population genomic dataset consisting of over 200 individual genomes from at least 14 subspecies to disentangle the out-of-Africa and out-of-Asia debate.

***Scipopus*: Finding a satisflying generic concept.**
K. G. Lindsay* and S. A. Marshall.
**lindsay.kate6@gmail.com*

Scipopus Enderlein is a large group of Neotropical flies often recognized by their orange heads and black bodies. Despite their seemingly conspicuously appearance, the genus

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lacks a proper generic definition and diagnosis. The goal of my research is to identify synapomorphies to define the genus and to differentiate *Scipopus* from the other three closely related genera in the *Scipopus* group: *Pseudeurybata* Hennig, *Phaeopterina* Frey and one undescribed genus. Preliminary DNA barcode data shows these four genera as distinct clades. The *Scipopus* group, along with several other Micropezid genera are relatively easily separated on the species level but on the generic level show high occurrences of homoplasy and character overlap, making them an evolutionarily interesting group to study.

Insect diversity, thermal tolerance, and thermal regulating behaviours along a neotropical elevational gradient.

A. Loureiro*, B. J. Sinclair, K. Cottenie, D. H. Janzen, W. Hallwachs, and M. A. Smith.
**a.loureiro@uoguelph.ca*

The biodiversity living on tropical mountains (the environment with the greatest biodiversity per unit area in the world) is under threat from the climate crisis. Furthermore, many tropical species remain undescribed, which puts us in a race against time to document both them and their ecology. Understanding how patterns of insect community structure and diversity are generated in tropical mountains, and how insect thermal tolerance influences behaviour, will lead to a better understanding of the evolution and maintenance of tropical diversity. This may also lead to better conservation practices and the prevention of their extinction.

Can the parasitoid wasp, *Trissolcus japonicus*, be used control the brown marmorated stink bug (*Halymorpha halys*, Stål) in Ontario?

C. M. MacDonald*, T. D. Gariepy, H. Fraser, and C. Scott-Dupree.
**cmacdo14@uoguelph.ca*

The parasitoid wasp, *Trissolcus japonicus*, parasitizes the eggs of the brown marmorated stink bug (BMSB). BMSB poses a significant threat to the agri-food industry in North America and no registered insecticides exist for its management in Canada. Therefore, *Trissolcus japonicus* is being considered as a candidate biological control agent. Before releasing *T. japonicus* in Ontario, its physiological host range is being assessed by testing its impact on native stink bugs. Additionally, after the discovery of *T. japonicus* in Maryland, USA and London, Ontario, its distribution is being investigated in Ontario. Preliminary data suggests that populations continue to persist in London.

Predatory capacity and life histories of two native North American nabids.

J. J. Mlynarek, A. Laflair, K. Zhang, P. Vilcu, K. Sim, R. Rizzato, D. Gagnier*, and R. M. Labbe.
**Dana.Gagnier@canada.ca*

Cultivated tomato, Solanum lycopersicon is an important crop grown in greenhouses and fields throughout Canada. Yet, managing pests on this crop continues to represent a major challenge, particularly in light of new invasive pests species for which few to no native natural enemies have been well investigated. The objective of this study was to better understand the biological control potential of *Nabis americoferus* and *Nabis roseipennis*

through conducting life history and predatory functional response trials. Our study shows that *N. americoferus* develops faster than *N. roseipennis* and they consume a lot prey but they eat more aphids than whiteflies. These findings contribute to improving our overall understanding of damsel bug natural history. This research can directly assist in the development of best practices for the application of nabids for the biological control of pests in greenhouse and field crops in Canada.

Thermal tolerance of rove beetles (Staphylinidae) across a forest/field ecotone.
I. Ostovar* and M. A. Smith.
**iostovar@uoguelph.ca*

The climate crisis and habitat fragmentation are exposing many animals to new thermal regimes, and so we need to better understand the thermal tolerance of the most diverse and abundant animals - the insects. For example, although they are amongst the most diverse animal families, there is limited information regarding the thermal tolerance of the Staphylinidae. We are estimating the thermal tolerance (CTmax) for staphylinids found across a forest/field ecotone on the University of Guelph campus. We expect that the assemblage of forest species will have lower CTmax than the assemblage in the field.

Tissue-specific transcriptome atlas of the asian longhorned beetle.
K. Ong*, A. S. Torson, A. D. Roe, and B. J. Sinclair.
**kong7@uwo.ca*

The Asian long-horned beetle (ALB; *Anoplophora glabripennis*) is an invasive wood-boring pest in North America and Europe. But, there are limited tools available for the functional characterization of the species. In this study, we characterize the transcriptomic profiles of developing larvae in five tissues; the subesophageal ganglion, midgut, hindgut, Malpighian tubules, and fat body. We assessed differences among tissues using principal component analysis, DESeq2, and fuzzy clustering. The differences were characterized into functional classes using gene ontology enrichment, and KEGG pathway analysis.

Understanding contributions of invertebrates to the seasonal diet of walleyes on Lake St. Joseph
A. Ricker-Held*, D. Beresford, D. de Kerckhove, and C. Wilson.
**aydenrickerheld@trentu.ca*

Walleye (*Sanxder vitreus*) are ecologically and economically significant for recreational and commercial fisheries across Ontario. Walleye are effective piscivores, but their foraging behaviour on alternative prey is largely unknown. Angler anecdotal evidence suggests that walleye target insects such as Mayflies (Ephemeroptera). My research examines the diets of walleye from May to September on Lake St. Joseph in northern Ontario, to determine the role insectivory plays in seasonal foraging. I will identify stomach contents of mature fish through morphologically analysis and eDNA methods. These results will inform long-term management strategies.

Improved trapping for detection and monitoring of pepper weevil (*Anthonomus eugenii).*
C. Russell*, B. Short, and R. Hallett.
**rcassie@uoguelph.ca*

The pepper weevil (PW, Anthonomus eugenii) has become a significant pest of field and greenhouse peppers in southwestern Ontario. Current monitoring strategies fail to detect PW presence before economic damage occurs. The efficacy of the current commercially available PW trap is under scrutiny, and a more effective trap design and lure are required. As part of a larger PW monitoring and management study, four alternative trap types were assessed for their ability to successfully capture PW. As adhesive cards were the most successful style of trap, new formulations of adhesive on yellow cards were evaluated for their ability to successfully retain PW and minimize escapes. A new adhesive formulation from Trécé Inc. shows great promise in retaining PW on cards for reliable detection.

Effects of urbanization on milkweed pollinator richness and abundance.
A. Tomchyshyn*, L. Miles, M. Johnson, and S. Breitbart.
**albert.tomchyshyn@mail.utoronto.ca*

Pollinator populations are critical to agriculture because they provide ecosystem services that are crucial for crop pollination. With current declines in pollinator richness and abundance, several studies have looked at the effects urbanization has on pollinator communities. In this study, I observed the richness and abundance of pollinators by visiting pollinator communities on *Asclepias syriaca* along a rural to urban gradient. Though pollinator richness did not differ from urban to rural sites, pollinators were more abundant within rural areas. Future research should elaborate on the relationship between *A. syriaca* abundance and pollinator abundance since this relationship is still relatively unknown.

Unearthing the adaptive significance of soil chambers built by insects.
K. F. Turnbull*, J. N. McNeil and B. J. Sinclair.
**kturnbu9@uwo.ca*

Many insects construct chambers in soil prior to winter dormancy or metamorphosis. However, the adaptive value of these structures is unclear. We use prepupae of the western bean cutworm, *Striacosta albicosta* (Lepidoptera: Noctuidae) to test three potential roles for soil chambers: that they confer space for metamorphosis, trap air during soil inundation, or exclude pathogens. By experimentally manipulating the integrity of chambers, our initial results show that these structures are necessary for prepupae to survive prolonged soil flooding. We will discuss possible mechanisms by which chambers might reduce the severity of hypoxia (i.e. low oxygen) in flooded soils.

Identifying genetic markers for deformed wing virus (DWV) levels in honey bees.
T. Tiwari*, R. Richardson, C. Kent, A. Dey, I. Conflitti, S. Rose, H. Patel, K. Dogantzis, A. Zayed, and BeeOmics Consortium.
**tiwari.tanushree@gmail.com*

The honey bee, *Apis mellifera* is a model organism for sociogenomics and is one of the most important managed pollinators. As such, recent threats to honey bee health are particularly alarming. The social honey bees live in highly crowded nests providing favorable conditions for the spread of infectious diseases. But honey bees have several social and individuals mechanisms for protecting themselves against disease. The BeeOMICS consortium has sequenced the genomes of approximately 1,000 honey bee colonies in Canada, which were evaluated for a number of traits, including the abundance of several pathogens within each colony. I plan to carry out genome-wide association studies (GWAS) on colony pathogen loads to gain a deeper insight of the genetics of immunity in honey bees. This research will set the groundwork for breeding disease resistant honey bees using marker assisted selection.

Activity and thermal tolerance of five sympatric species of Ontario ants.
T. Venart-Johnson*, B. Cote, L. Rocha-Sersanti, N. Taji, A. Loureiro, and M. A. Smith.
**tvenartj@uoguelph.ca*

Range limits and foraging behaviours of arthropod species are affected by abiotic factures (temperature and precipitation) and competitive interactions. For example, one species of ant, (*Prenolepis imparis*) is known to be more active at cooler temperatures (and less active during the heat of the summer) than other co-occurring ant species. This pattern is thought to be due to competition avoidance, but what is unknown is whether these differences correspond with differences in the critical thermal maximum (CTmax) for these species. To determine this, we measured CTmax and activity for five sympatric ant species across 38 degrees of temperature.

Presentation abstracts

Using thermal biology to choose a climate-matched biological control agent for an emerging agricultural pest.
N. Amiresmaeili*, T. Gariepy, and B. Sinclair.
**n.amiresmaili@gmail.com*

Biological control is an important component of agricultural insect pest control but not all introductions of biocontrol agents are successful. This is possibly because the source populations for the biocontrol agents are adapted to climates significantly different from the release locality. We are using thermal biology to choose a climate-matched population of *Trissulcus japonicus* (Hymenoptera: Scelionidae), a parasitoid wasp that is a natural enemy of invasive Brown Marmorated Stink Bug [BMSB; *Halyomorpha halys* (Hemiptera: Pentatomidae)] in Canada. There is a very high likelihood that our results will be directly used to inform decisions about strains of parasitoid chosen for release.

Mitochondrial physiology of the freeze-tolerant cricket, *Gryllus veletis*.
C. Baragar*, B. Sinclair, J. Lebenzon, and M. Duell.
**cbaragar@uwo.ca*

Freeze-tolerant insects can withstand internal ice formation. During freezing, cells osmotically dehydrate and shrink, and whether this impairs mitochondrial function is unknown. The spring field cricket (*Gryllus veletis*) becomes freeze-tolerant through cold acclimation, which results in a decreased whole-animal metabolic rate. During recovery from freezing, whole-animal metabolic rate in *G. veletis* increases. I propose to assess whether changes in whole-animal metabolic rate during acclimation and recovery from freezing are mirrored in mitochondrial respiration rates. I hypothesize that during acclimation, *G. veletis* suppresses mitochondrial respiration rates to protect its mitochondria from future freezing, or it repairs mitochondrial damage accrued during freezing.

How to correct for irregular trapping times, and why you need to.
D. V. Beresford.
davidberesford@trentu.ca

Sampling insect populations often requires setting traps for set periods of time such as hourly, daily, or weekly. Because insects are poikilotherms, any temperature changes during the trapping periods will cause insect activity to vary accordingly. Using a stable fly sticky trap example, I demonstrate that this effectively means that such trapping takes place on irregular time intervals in terms of physiologically relevant time. I argue this requires correcting trap catch numbers by converting them into catch per unit sample period, where sample period is measured in degree days.

Behavioural variation among sweat bee species from the Niagara region.
L. Corbin.
lc15kl@brocku.ca

Sweat bees are key models in understanding the evolutionary transitions to eusociality due to their social diversity. Many sweat bee species' behaviours remain unknown, limiting our knowledge on the behavioural variation among taxa and social patterns within genera. Thus, describing social traits in sweat bees provides further insight on their behaviour and the mechanisms underlying social evolution. The objective of this study was to describe the social behaviour of two *Lasioglossum* (*Dialictus*) species, *L. hitchensi* and *L. ellisiae*, from pan trapped specimens. Comparative analyses between these species demonstrates social variation in closely related taxa from a local region.

Developmental rates of emerald ash borer eggs can be used to improve its management in global maritime regions.
K. W. Dearborn*, S. M. Smith, C. J. K. MacQuarrie, and D. J. G. Inward.
**Kenneth.w.dearborn@gmail.com*

The emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is an invasive Asian beetle that has killed millions of North American ash trees. Stage-specific growth rates are needed to better manage and reduce long-term impacts. Here, we quantify the development rate of the initial life stage across biologically-relevant temperatures (7-35°C) to predict egg phenology. Developmental time was shorter as temperatures increased

from 15-35 °C. Establishing the approximate duration eggs take to develop and are present on trees will improve forest management by refining biological control release timing. Quantification will be particularly important when applied to cooler summer maritime regions.

Surviving the polar vortex: extreme cold tolerance of the emerald ash borer.
M. E. Duell*, A. D. Roe, C. J. K. MacQuarrie, and B. J. Sinclair.
*mduell@uwo.ca

The emerald ash borer (*Agrilus planipennis*, EAB) is a lethal pest to ash trees throughout North America. In 2018, EAB was confirmed in Winnipeg, which is much colder than areas where it was previously established. Cold tolerance models suggest the 2019 Polar Vortex should have killed all overwintering Winnipeg EAB with air temperatures in of-34°C. However, some Winnipeg EAB survived exposure to -50°C. Supercooling points ranged from -25°C to -52°C, much lower than those from southern Ontario. This increased cold tolerance suggests that EAB could expand its range in Canada and is driven by high hemolymph osmolality with glycerol accumulation.

Functional morphological differences in beetle elytral structures along a neotropical elevation gradient.
M. Elmankabady*, A. Loureiro, D. H. Janzen, W. Hallwachs, and M. A. Smith.
*melmanka@uoguelph.ca

Insect cuticle micro-structures are responsible for multiple adaptations to abiotic conditions. We used Staphylinidae (rove beetles) collected along a neotropical elevation gradient to test whether this structural diversity matched prior estimates of taxonomic and genetic diversity. We used scanning electron microscopy (SEM) to measure if elytral structures corresponded with functions expected to be favoured within forests found along that gradient (low elevation dry forest, mid-elevation rain forest and high elevation cloud forest). Preliminary analyses suggest an association between elytral structural morphology and forest type, suggesting a relationship between elytral type and functional diversity.

Analysis of the *Drosophila melanogaster* anti-ovarian response to honey bee queen mandibular pheromone.
K. C. Galang*, J. R. Croft, G. J. Thompson, and A. Percival-Smith.
*bandem95@my.yorku.ca

In *Apis mellifera*, the anti-ovarian effect of queen mandibular pheromone (QMP) on workers can, surprisingly, be induced in other insects, including fruit flies; females exposed to synthetic QMP develop smaller ovaries with fewer eggs. We use the *Drosophila melanogaster* model to identify 9-oxo-2-decenoic acid and 10-hydroxy-2-decenoic acid (10HDA) as the components of QMP that are essential for the anti-ovarian response. In addition, we used olfactory receptor GAL4 drivers and a neuronal activator to test whether candidate neurones are potential labelled lines for a decenoic acid response. We identified Or-49b as a potential candidate receiver of the 10HDA signal.

At-risk bumble bees (*Bombus* spp.) show preference for invasive tufted vetch in protected areas.
S. D. Gibson*, A. L. Liczner, and S. R. Colla.
**shelbydgibson@gmail.com*

Declines have been reported in certain species of bumble bees historically present in southern Ontario, including: Yellow bumble bee (*B. fervidus*) (Fabricus, 1798), American bumble bee (*B. pensylvanicus*) (DeGeer, 1773), and Yellow-banded bumble bee (*B. terricola*) (Kirby, 1837). Threats to bumble bee populations include: land-use changes, habitat loss, climate change, pathogen spillover, and pesticide use. A solution has been to encourage "bee-friendly" planting. Our question is whether there is a difference in co-occurring at-risk bumble bee floral use in protected areas. The results of a redundancy analysis show a difference in foraging between common and at-risk bumblebee species.

Using pastry caterpillars to address questions in ecology and evolution through experiential learning.
T. J. Hossie.
thossie@trentu.ca

Using artificial prey to examine patterns of predation by wild predators has proven to be an important research tool for biologists, but is also an effective way for educators to teach ecology and evolution by observation and experiment. Pastry caterpillars in particular have been employed to investigate questions about the efficacy of specific adaptations (e.g., countershading, eyespots, polymorphism), however the questions that can be addressed by this technique is limited only by the investigator's own creativity. In this talk I outline this approach and how it can be used to teach ecology and evolution across a range of grade levels.

Negative selection in social insects.
A. Imrit*, B. A. Harpur, K. A. Dogantzis, and A. Zayed.
**imarshad@my.yorku.ca*

Eusociality, characterized in part by cooperative brood care, and reproductive division of labor, evolved independently several times in insects. The evolution of eusociality has been hypothesized to lead to differences in the extent of both positive and negative selection. While population genomics studies of eusocial insects have so far focused on positive selection, there has been no study of the extent of negative selection in social insects, and its relationship to the evolution of caste-biased genes. To address this knowledge gap, my research will estimate the extent of negative selection in honey bees, bumble bees, and wasps, through analysis of published population genomic datasets. My study will compare the relationship between the strength of negative selection and caste-specific patterns of gene expression, and examine if the strength of negative selection correlates with the level of social complexity in this species triad.

Building *Culicoides* (Diptera: Ceratopogonidae) DNA barcode reference libraries to support molecular biosurveillance protocols.
L. Janke*, R. Young, Y. Millian-Garcia, I. Thompson, T. Quintana-Loeza, and R. Hanner.
**jankel@uoguelph.ca*

Culicoides (Diptera: Ceratopogonidae) midges are known vectors of various animal diseases that are of concern to the agricultural industry. A better understanding of the phylogeographic distribution of these species and the infectious agents they may carry could help inform disease management and prevention decisions. Emerging molecular biosurveillance protocols have the potential to support these objectives in a timely, cost-effective manner and at a scale not possible using conventional methods. However, a well-curated reference sequence library derived from properly identified specimens of known provenance together with an accessible information system to host this information is required to undertake such programs. To achieve this objective, the Canadian Food Inspection Agency is collaborating with the University of Guelph to populate the Barcode of Life Data System with additional information on expert-identified *Culicoides* specimens destined for multi-gene barcoding. Together, we have populated specimen records for more than 220 individuals with high-resolution composite images that reveal key diagnostic characters used to support their identifications. This work will expand our molecular and morphological knowledge of *Culicoides* and help support a Canadian molecular metabarcoding biosurveillance protocol.

Gut yeasts accelerate development in *Drosophila melanogaster* larvae.
Y. Jimenez-Padilla*, M.-A. Lachance, and B. J. Sinclair.
**yjimenez@uwo.ca*

The gut of *Drosophila melanogaster* houses a diverse community of microbes, including bacteria, yeasts, protozoa, and viruses. Yeasts are often provided to flies as nutrients, but their role in the gut microbiota is poorly understood. I studied the effects of *Saccharomyces cerevisiae* (the yeast commonly used in lab settings) and *Lachancea kluyveri* (a yeast originally isolated from the gut of some *Drosophila* spp.) on fly development. I reared *D. melanogaster* either as axenic (free of microbes), or gnotobiotic (with a known yeast species in their gut), and recorded the pupation and eclosion times. Both yeasts reduce larval development time by c. 23 %, and the effect is not purely dietary.

Sperm competition during sperm storage process in honey bee (*Apis mellifera* L.) queens.
Y. Kahya, H. V. Gencer, and A. Zayed.
**kahyasin@gmail.com*

Sperm competition is expected to occur in honey bees during migration of sperm from several drones into the spermatheca of the queen shortly after mating and/or during sperm use by the queen for fertilizing the eggs. The first aim of the study was to develop a pyrosequencing based method enabling the genotypic identity of the heterospermic contents in the spermathecae of instrumentally inseminated queens (IIQs) to detect sperm competition

during sperm migration process. The second aim was to disclose whether injection order of semen and queen genotype (cryptic female choice) affect the proportions of two drone genotypes in spermathecal contents of these IIQs or not.

Beetle, it's cold outside: The metabolomic and transcriptomic changes that drive cold tolerance in the Colorado potato beetle (*Leptinotarsa decemlineata*).
J. E. Lebenzon*, A. S. Torson, and B. J. Sinclair.
**jlebenzo@uwo.ca*

The Colorado potato beetle overwinters in diapause as an adult, where it is likely to encounter sub-zero temperatures and risk freezing of its body fluids. Beetles have evolved strategies to avoid freezing altogether and become cold-tolerant during winter, but we still do not understand the physiological mechanisms that drive survival at these low temperatures, and the extent to which their diapause programme confers cold tolerance. We used an 'omics approach to uncover the metabolomic and transcriptomic differences between diapause and cold tolerance in the Colorado potato beetle, and identified several metabolic pathways that could drive differences in sub-zero temperature survival.

Biological control of the emerald ash borer.
C. J. K. MacQuarrie, M. Gray, G. Jones, and K. Ryall.
**christian.macquarrie@canada.ca*

The emerald ash borer is the most significant forest pest in Ontario, killing hundreds of thousands of trees since the time it was discovered in Windsor, Ontario in 2002. In 2013, a biological control program was established to introduce some natural regulation of the insect in Ontario, and throughout Canada. This program has resulted in the successful introduction of two larval parasitoids *Tetrastichus planipennisi* and *Spathius galinae*, and an egg parasitoid *Oobius agrili* at multiple sites in the province. Ongoing work has been examining the impact and spread of these species from the initial release sites.

Susceptibility of the swede midge parasitoid, *Synopeas myles* (Hymenoptera: Platygastridae) to foliar applied insecticides.
C. McLennan*, A. Gradish, A. Frewin, and R. H. Hallett.
**cmclen01@uoguelph.ca*

Swede midge *Contarinia nasturtii* (Keiffer) (Diptera: Cecidomyiidae) is a major pest to cruciferous vegetable and canola production in North America. Native to Eurasia, the swede midge is now distributed from the east coast of North America to Minnesota. In 2016 a swede midge parasitoid, *Synopeas myles* (Walker) (Hymenoptera: Platygastridae), was discovered in Ontario. Establishment of this natural enemy, also native to Europe, has developed an interest in conservation biological control efforts. Foliar insecticides containing the active ingredients chlorantraniliprole and lambda-cyhalothrin are currently registered in Canada for swede midge management in canola. Determining susceptibility of *S. myles* to these insecticides is important for determining the compatibility of insecticide use and conservation biological control efforts.

Natural history observations of leaf mining insect-*Astereae* associations.
J. J. Mlynarek.
julia.mlynarek@canada.ca

Leaf mining insects are intimately associated with host plants during their larval stage. Leaf miner-plant interactions should therefore be a perfect system to test eco-evolutionary hypotheses. But the patterns of host ranges remain unclear because of rearing and identification challenges. I set out to have a clearer picture of the leaf mining insects (Diptera, Coleoptera and Lepidoptera) feeding on plants in the *Astereae* (Asteraceae) tribe in Eastern Canada. I will highlight the interesting host range patterns and try to explain them through taxonomic, ecological and evolutionary lenses.

Gene Expression Profiles in Honeybee Brains using the Food Search Box Protocol.
B. Morrison* and A. Zayed.
**bandem95@my.yorku.ca*

Honeybees are central place foragers. Part of what allows the bees to improve their foraging skills is their ability to learn where food patches are relative to the hive, avoid predation risk and navigate new locations. The molecular mechanisms underlying this learning ability have been investigated by using Proboscis Extension Reflex (PER) and free-flight learning protocols. We know that during learning, gene expression in the brain changes in the short-term and long-term. Here, we utilize a newly developed learning protocol called the Food Search Box (FSB) paradigm to study spatial learning in the honeybee. By conducting time-course experiments in the context of FSB, we are investigating how gene expression changes over time in response to spatial learning.

The enhancement of non-crop habitat to support natural enemy populations at the Holland Marsh, ON.
D. B. Muldoon*, A. Stinson, M. R. McDonald, and C. Scott-Dupree.
**dmuldoon@uoguelph.ca*

The Holland Marsh (HM), Ontario, is an agroecosystem with a primary focus on carrot and onion production. It contains negligible uncultivated habitat to support natural enemies (NE) of insect pests of carrots and onions. Recent upgrades to the HM drainage system have provided an opportunity to investigate how enhancements to canal berms can affect NE populations. Five berm plots were established, each with three treatments: (1) Control; (2) Floral Enhancement, and (3) Floral + Shrub Enhancement. Active and passive trapping was used to determine the abundance and richness of NE and insect pests at these berm plots.

Morphometric analyses from zones of sympatry and ocellar structures confirm species status of *Apis laboriosa.*
G. W. Otis*, N. Kitnya, J. Chakravorty, and A. Brockmann.
**gotis@uoguelph.ca*

Apis laboriosa, the cliff-nesting honeybee of the Himalayan region, is accepted as a valid

species by most researchers. However, due to the lack of a comprehensive taxomonic analysis, a few continue to consider it to be a larger, blacker, hairier subspecies of the widespread *Apis dorsata*. We sampled foragers of two colour morphs of [Megapis] from 3 zones of sympatry in NE India. Morphometric analyses separated the bees into two non-overlapping clusters. Characters of the ocellar region on the heads of both workers and drones allow for unequivocal identification, thus further confirming the species status of *Apis laboriosa*.

Local landscape composition and colony-wide genetic diversity predict honey bee colony size.
R. T. Richardson*, C. F. Kent, T. Tiwari, I. M. Conflitti, A. Zayed, and the BeeOMICs Consortium.
**rtr87@yorku.ca*

Few studies have examined how intracolonial genetic diversity and local landscape composition impact honey bee colony health and productivity. Further, such studies have been limited in sample size or experimental design. In the BeeOmics project, approximately 1,300 colonies situated across five Canadian provinces were phenotyped and genotyped for an associational study. Here, we used linear mixed effects modelling to investigate these data for associations between intracolonial genetic diversity, local landscape composition and measures of fall colony size. Results show that both intracolonial genetic diversity and local landscape composition predict measures of fall colony size.

Dispersal abilities and habitat suitability of a newly introduced butterfly in Canada, *Polyommatus icarus*.
S. A. Rivest* and H. M. Kharouba.
**srive046@uottawa.ca*

The frequency of species introductions is on the rise globally. One newly introduced butterfly, the European Common Blue (*Polyommatus icarus*), is expanding its range around Montréal, QC. To understand its potential for range expansion in the future, we assessed the dispersal capacity of *P. icarus* adults. We also characterized its habitat suitability at two scales: local and landscape-level. We found that *P. icarus* adults only rarely fly long distances (~900m) and that they are most abundant where there is more floral cover, where there is an intermediate amount of habitat disturbance and where their preferred larval foodplant is found.

Using parasitoid wasp *Jaliscoa hunteri* to target a major pepper crop pest in Canada.
R. Rizzato*, D. Catalina Fernández, D. Gagnier, and R. Labbe.
**rebecca.rizzato@Canada.ca*

The pepper weevil, *Anthonomus eugenii* (Coleoptera: Curculionidae) is an important pest of pepper crops in Canada. One possible means of reducing its populations is through targeting immature life stages through parasitism by parasitoid *Jaliscoa hunteri* (Hymenoptera: Pteromalidae). However until now, the mechanism employed by this wasp has been poorly

understood. In this study, results of laboratory and greenhouse trials are presented which better elucidates the conditions required for *J. hunteri* to affect pepper weevil in greenhouse or field pepper crops. The implications of our findings on the development of best practices for pepper weevil biological control in Canada are discussed.

Carnivorous plants and bog arthropods: diversity and trophic level.
A. Semenuk*, P. Moldowan, and M. A. Smith.
**asemenuk@uoguelph.ca*

Carnivory in plants has evolved independently nine times as a method of acquiring nitrogen in nutrient-poor ecosystems. Prey-capturing mechanisms may differ between carnivorous plant species, such as the pitfall trap of the pitcher plant (*Sarracenia purpurea*) and the sticky-trap of the sundew (*Drosera rotundifolia*). Does this difference in trapping-mechanism result in differences in captured prey? We conducted DNA barcoding and stable isotope analysis of insects collected from carnivorous plants in Algonquin Park to identify the diversity and trophic level of carnivorous plant prey. We will present findings regarding how unique the prey assemblages are for two neighbouring carnivorous plant species.

Thermal tolerance of a hyperdiverse insect group along a neotropical elevational gradient.
M. A. Smith*, A. Loureiro, B. Sinclair, D. Janzen, and W. Hallwachs.
**salex@uoguelph.ca*

The fine-scale distribution of neotropical species across elevation is thought to be prescribed by low variability in abiotic factors such as temperature and precipitation. We asked whether the thermal tolerance (CTmax) of a hyperdiverse insect family (Staphylinidae) would correspond with this prediction (namely a negative relationship between CTmax and elevation). In a preliminary study, we analysed the CTmax for 30 species across 1500m in Costa Rica. Our results suggest that even small differences in elevation correspond with community-level differences in thermal tolerance. Diverse, abundant, high-elevation staphylinid assemblages may be un-prepared for coming increases in temperature associated with the climate crisis.

Transcriptomic changes during diapause in the Asian longhorned beetle.
A. S. Torson*, A. Al Baz, A. D. Roe, and B. J. Sinclair.
**atorson@uwo.ca*

To cope with harsh winter conditions, many insects enter a state of developmental arrest known as diapause – a phenotype characterized by decreased metabolic rate and increased stress tolerance. The Asian longhorned beetle, *Anoplophora glabripennis*, is an invasive species whose invasion risk to Canadian forests is likely correlated with its overwintering capacity. The objectives of this study were to 1) test the hypothesis that *A. glabripennis* overwinter in diapause and 2) determine transcriptomic signatures of the diapause phenotype using machine learning. We observed tissue-specific changes in diapausing larvae and identified suites of transcripts that correlated with physiological changes during diapause.

Heritability of neonicotinoid detoxification in honey bees.
N. Tsvetkov*, A. Khalili, I. Conflitti, and A Zayed.
**nadiats@yorku.ca*

The toxicity of neonicotinoids (NNIs) varies greatly between honey bee sub species. In order to investigate the potential genetic factors influencing the different tolerances to NNIs, we exposed honey bee workers to an NNI and recorded their 24 hour survival rate. We then genotyped the bees using microsatellites and found a statistically significant effect of patrilines on mortality. Afterwards, we sequenced three detoxification genes from 100 bees in order to determine the allelic variation between the patrilines with the most extreme survival rates. The effects of NNIs on honey bees is still a hotly debated topic, understanding the genetic mechanisms behind the natural variation of NNI detoxification could help reconcile seemingly contradicting results in the scientific literature.

***Stipulosina*, a new genus of Limosininae (Diptera: Sphaeroceridae) associated with bamboo stipules in Ecuador.**
T. Yau* and S. A. Marshall.
**tyau@alumni.uoguelph.ca*

Thirty specimens of Sphaeroceridae collected from bamboo stipules in the Ecuadorian Andes in 2002 included four new species of an undescribed genus. The publication of *Stipulosina* was held back pending further recordings of the unusual habitat restriction. In May 2019 we visited a site near the original collection locality of *Stipulisina*. There we collected more specimens, tested the hypothesis that they are stipule inhabitants, and learned more about their biology and natural history. We examined eight bamboo species from two different elevations, finding *Stipulosina* only on *Chusquea scandens* with high specificity on the stage and condition of the bamboo.

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amanda.roe@canada.ca
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Secretary: M. LOCKE
Agriculture and Agri-Food Canada
K.W. Neatby Building, 960 Carling Avenue,
Ottawa, ON K1A 0C6
entsocont.membership@gmail.com
michellemlocke@gmail.com
Treasurer: A. MACNAUGHTON
University of Waterloo
200 University Ave W, Waterloo ON N2L 3G1
amacnaughton@uwaterloo.ca
Directors:
M. RICHARDS (2018-2020)
Department of Biological Sciences, Brock University
1812 Sir Isaac Brock Way, St. Catharines, ON L2S 3A1
mrichards@brocku.ca
J. MLYNAREK (2018-2020)
Harrow Research and Development Centre,
Agriculture and Agri-Food Canada
2585 Essex County Rd 20, Harrow, ON N0R 1G0
julia.mlynarek@canada.ca
J. DEWAARD (2019-2021)
Centre for Biodiversity Genomics,
Biodiversity Institute of Ontario,
University of Guelph
50 Stone Road East, Guelph, ON N1G 2W1
dewaardj@uoguelph.ca
T. BAUTE (2019-2021)
Ontario Ministry of Agriculture,
Food and Rural Affairs
Ridgetown, ON
tracey.baute@ontario.ca
M. MILLER (2020-2022)
University of Guelph
50 Stone Road East, Guelph, ON N1G 2W1
meredithellenmiller@gmail.com
Z. KULLIK (2020-2022)
59 Camelot Dr Floor 2W, Room 239,
Ottawa, ON K2G 5X4
sigrun.kullik@canada.ca
ESO Regional Rep to ESC: A. SMITH
Department of Integrative Biology,
University of Guelph
50 Stone Road East, Guelph, ON N1G 2W1
salex@uoguelph.ca
Webmaster: K. FLEMING
Trent University
1600 West Bank Drive, Peterborough, ON K9J 7B8
kaitlynflemin@trentu.ca
Newsletter Editors:
L. DES MARTEAUX
Biology Center CAS
Branišovská 1160/31, 370 05
České Budějovice, Czech Republic
ldesmart@gmail.com
K. SHUKLA
Department of Chemistry and Biology,
Ryerson University
350 Victoria Street, Toronto, ON M5B 2K3
kruti.shukla@gmail.com
Student Representatives:
K. FLEMING
Trent University
1600 West Bank Drive, Peterborough, ON K9J 7B8
kaitlynflemin@trentu.ca
A. DOLEZAL
University of Guelph
50 Stone Road East, Guelph, ON N1G 2W1
adolezal@uoguelph.ca

JESO Editor: C. MACQUARRIE
Natural Resources Canada, Canadian Forest Service
Great Lakes Forestry Centre
1219 Queen Street East,
Sault Ste. Marie, ON P6A 2E5
JESOEditor@gmail.com
JESO Associate Editor:
A. BENNETT
Agriculture and Agri-Food Canada
K.W. Neatby Building, 960 Carling Avenue,
Ottawa, ON K1A 0C6
andrew.bennett@agr.gc.ca
Copyeditor and Technical Editor:
T. ONUFERKO
The Beaty Centre for Species Discovery,
Canadian Museum of Nature
P.O. Box 3443, Station D Ottawa, ON K1P 6P4
tonuferko@nature.ca

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